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Vol. I

MEMOIR

ON THE

GEOLOGY OF CENTRAL FRANCE;

INCLUDING THE

VOLCANIC FORMATIONS

OF

AUVERGNE, THE VELAY, AND THE VIVARAIS.

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a
Vol. I

By G. POULETT SCROPE, F.R.S. F.G.S. &c.

LONDON:

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" Ce n'est pas avec d'immenses connoissances qu'on parvient toujours à mieux voir que les autres, c'est par une bonne méthode toujours secondée de l'observation. Surtout l'observation. C'est ce qui fait que le Chimiste enfermé au milieu de son laboratoire et de ses fourneaux, est souvent un médiocre naturaliste et un mauvais géologue : il voit bien là peut-être, comment la Nature a fait dans une pierre ; mais c'est dans les champs ; c'est sur la cime des monts, qu'on voit comment elle a fait sur le globe."—*Montlosier, Essai sur la Théorie des Volcans d'Auvergne*, page 8.

" Il n'y a peut-être pas dans tout l'univers une contrée où les terrains volcaniques soient plus variés, mieux liés entre eux, et par conséquent plus instructifs que dans le milieu de la France."—*Fox Bocon, Lettre à Pictet.*

PRINTED BY RICHARD TAYLOR,
SHOE-LANE.

ALEBE FLAMMAM.

TO

JOHN POULETT THOMSON, ESQ.

OF WAVERLEY ABBEY,

THE FOLLOWING PAGES

ARE INSCRIBED

WITH EVERY SENTIMENT OF RESPECT AND GRATITUDE,

BY HIS AFFECTIONATE SON

THE AUTHOR.

PREFACE.

TOWARDS the end of the last century, men of science became convinced of the futility of those crude and fanciful speculations on the original state of the earth, in which cabinet geologists had for some time indulged; and justly perceived that the only sure road to the true history of our planet lies in a minute and practical study of those portions of its surface which are open to our examination, and in their comparison with the results of those changes and operations which the ever-active hand of Nature is still carrying on upon that surface. In the commencement of this investigation, the real business of Geology, they were led, perhaps by the striking nature of the phænomena, to direct their attention particularly to volcanic regions. Dolomieu, Spallanzani, and Sir W. Hamilton explored with great perseverance the active volcanos of the South of Europe. Desmarest, Faujas de St. Fond, Fortis, and Strange, discovered and proclaimed the volcanic nature of many extensive rock-formations, which presenting less obvious marks of their igneous origin, had been overlooked or mistaken by preceding observers.

At this period WERNER made his appearance in the field of Geology; and by the fascination of his enthusiasm, the novelty of his theories, and the apparent truth of the limited number of facts on which they were built, drew triumphantly after him the whole body of European naturalists, changed for a time the direction of geological research, and confined it to that series of formations which he was the first to point out. Werner unfortunately enjoyed no opportunity of studying the phænomena of active volcanos; and that he was totally unacquainted with their nature and effects, is evident from his supposing them analogous to the placid combustion

of ignited coal-beds. From this cause, and in part perhaps from others, he seems to have entertained a contempt,—it might almost be said an antipathy, to them. His numerous disciples, and those of the schools founded upon his system, inherited this aversion. They followed his example, in confining the effects of these extraordinary subterranean agents within the narrowest imaginable compass, and reducing to a comparative nothing the share they have had in the construction or derangement of the globe's actual surface.

In this manner the study of volcanos not only lost on a sudden the extreme importance which was once almost exclusively attached to it, but, as we generally run from one excess into another, became depreciated far below its real value, and of course proportionately neglected. The time occupied in it was counted as lost, and the knowledge obtained as rather injurious than advantageous to the progress of the new science of *Geognosy*. Volcanic products were looked upon more in the light of artificial than natural substances; as accidental excrescences or superfœtations disfiguring the crust of the earth, bearing no relation to the general system, and disclosing none of the secrets of its arrangement. These ideas are at length yielding to a sounder and less prejudiced spirit of inquiry; and this, as well as some other erroneous dogmas of the Wernerian school, will probably before long be generally estimated at their true value.

It may be justly suspected, indeed, that those who have at any time thought and spoken so slightingly of volcanic agency, were but little acquainted with the nature or extent of its phænomena. It is not the comparison of cabinet specimens, nor even the examination of a single volcano in action, that can impart any adequate knowledge of the changes this power is capable of effecting in the surface of a country, or the appearances which its products may occasionally assume. Those whose ideas on the geological character of volcanic substances are solely drawn from sources of this limited nature, may be justified in rejecting such a proposition as that the Flœtz Trap rocks, for instance, are of this nature. Having neglected the intermediate stages of the process by which the members of this forma-

tion have acquired their characteristic features, and acquainted themselves only with the extremes of the series, they are led to consider them as too remote and dissimilar to be in any way connected.

These considerations induced me to follow up the examination of volcanos in their active state by that of a region in which they have been long extinct, and in which it is natural to suppose that their products may have undergone considerable modifications by various accidental circumstances connected with their antiquity, but above all by their long exposure to meteoric influence. I had previously explored the volcanos of Italy and its islands, Vesuvius, Ætna, Stromboli, and Vulcano, and repeatedly traversed that band of territory on the western side of the Apennines, comprised between Santa Fiora in Tuscany and the Bay of Pæstum, which is known to have been the theatre of volcanic phænomena on a very extensive scale.

The next step seemed to be the examination of Auvergne and its neighbouring districts;—a country incontestably replete with the products of extinct volcanos, passing indeed as the type of this class of formations, and where they are peculiarly interesting from being found in immediate contact with, not only the (so called) primitive class of rocks, but that also which is supposed to have been last deposited, the tertiary and freshwater strata.

For this purpose, in the beginning of June 1821, I established myself at Clermont, the capital of the department of the Puy de Dome, and from thence, as a central point, made excursions through the vicinity; successively transferring my head-quarters as it became convenient, to the Baths of Mont Dor, Le Puy (Haute Loire), and Aubenas (Ardêche). The plan I constantly pursued, and which experience fully confirmed as the best, was to explore my own way hammer in hand, with no other guides than a sheet of Cassini's map and a compass. I found it an unnecessary precaution to carry arms. The Auvergnat mountaineer is always eager to offer assistance, hospitable and respectful, in spite of his unconcealed astonishment at the apparent object of a geologist's researches. I do not indeed recollect ever meeting with difficulties, but once; when,

having accidentally left my passport at Clermont, I was arrested by the *gens d'armes* of Besse, a small retired town on the Mont Dor, and, after a fruitless expostulation with a superannuated *Juge-de-paix*, was imprisoned for the night, and marched off during the two next days by a circuitous route to Clermont.—I mention this as a warning to any one who may, like myself, explore his way through any part of France, and imagine that a harmless geologist runs no risk of being mistaken for a conspirator, and made a prisoner of state.

I fortunately entered upon the examination of the great geological features which distinguish this country, not unprepared with a certain amount of knowledge as to the nature of subterranean or volcanic agency, but wholly uninfluenced by any previously formed opinions on the district before me; having laid down and adhered to a resolution not to open any author who had written on the subject, until I had made myself sufficiently acquainted with it to be able to decide on the degree of credit to which his remarks were entitled. I was, in short, thoroughly determined to form an opinion exclusively my own; and to this end to see with my own eyes, verify every fact myself, and neither take up with the remarks or conclusions of any other observer. In the same spirit I have recorded the observations contained in the following Memoir, which pretends to little other merit than that of independence and fidelity.

Although the chief interest which attaches itself to this district arises from the volcanic rocks so profusely scattered over its surface, yet its geology presents also many other points of no inconsiderable importance, and which as yet have been but slightly and partially noticed, in different unconnected publications, either by French or English geologists *. A general account of the country upon which

* Since I quitted Auvergne, a Society for the prosecution of researches in Natural History, and particularly in Mineralogy and Geology, has been established at Clermont. It has already published some papers of interest, especially an account of the discovery of a vast collection of bones, belonging according to Cuvier to thirty different animal species, in the volcanic tufa of the Mont Perrier near Issoire. See *Bulletin des Sciences*, No. 3. March 1826.

the volcanic products under review are situated, was likewise absolutely necessary to the illustration of their geological connections or chronology.

For these reasons I have given up the first section to a brief survey of the primitive, secondary, and tertiary or freshwater formations, which together with the superincumbent rocks of volcanic nature constitute the high lands of the interior of France. The remainder of the work is exclusively dedicated to the description of the volcanic products which I have had the opportunity of observing in that region, and embraces, I believe, with very few exceptions, all that exist there.

The Drawings which accompany this Memoir are professedly nothing more than geological sketches; but as such, their accuracy may be relied on. Of the two Maps which were judged requisite for the complete illustration of the subject; one, viz. that of the Monts Dome, was drawn upon the spot by myself, taking for a basis that of Cassini, correcting its errors of detail, and marking in colours the superficial extent of the various lava-streams, which I took considerable pains to ascertain with accuracy by careful and repeated examination. The other map, which embraces the greater part of the high primitive platform of Central France, is compiled from the best materials I could procure, and principally from the reduction of Cassini lately published in 24 sheets at Paris, combined with my own observations: and coloured chiefly from the latter source.

A series of specimens of the rocks occurring within the district described, has been presented to the cabinet of the Geological Society of London. They will be therefore easily accessible to those who may desire to consult them.

MILAN,
April 6th, 1822.

This Memoir with the preceding Preface was written and dispatched to England at the above date. It remained unpublished, from the known and natural unwillingness of publishers to undertake scientific works with expensive plates. The interest which is

now beginning to spread extensively as to the nature and products of volcanos, together with the persuasions of my geological friends, have induced me to hazard its impression. Those who intend visiting Auvergne and the Velay will find it useful as a *guide*; and it was with this object that I have occasionally entered into local details, with a minuteness which must be frequently tiresome to general readers. I would recommend to such, the Plates and the brief explanatory remarks which are given as an appendix to the Memoir.

A few words may as well be said in this place on another subject.

As the following pages contain a part of the series of observations on volcanic districts which led me to adopt the opinions on the nature and mode of action of Volcanos and Earthquakes, which I have published in a separate Essay *, (of which indeed the present work may be partly considered an appendix, or *piece justificative*,) I take this opportunity of explaining one or two parts of that theory, where my meaning has I believe been but imperfectly understood.

One of the points on which I differ very widely from the greater number of writers on the theory of volcanic phænomena is, in supposing that most lavas, *at the time of their flowing on the surface of the earth and in open air*, are not in a state of *fusion*, (understanding by *fusion*, the complete reduction of a substance in every part to its integrant molecules, not merely its more or less partial liquefaction by heat,) but consist of solid crystals that slip or glide over one another owing to the intervention of minute quantities of an elastic fluid, which is generated† throughout the substance of the

* Considerations on Volcanos. 8vo. 1825.

† It seems probable that the generation of this elastic fluid must result from the partial vaporization of the surfaces of the crystals, on those points where the force of cohesive affinity is weakest. How it happens that such a process gives rise to the production of *aqueous* vapour, (which certainly forms the largest proportion of the aëriform matter discharged by lavas during an eruption,) is a problem, which in the present state of chemistry we are unable to solve; any more than to explain the changes that seem to take place at the same time in the mineral composition of the crystalline residuum, which seems during this process to be sometimes transformed from trachyte into basalt, from granite into greenstone or diallage rock, &c. It would be highly desirable to ascertain by experiment the effect of exposing a

confined and intensely heated lava (at such a temperature perhaps as would sublime all its constituent minerals under atmospheric pressure alone), when the pressure upon it is suddenly diminished, by the yielding of the overlying rocks, and the creation of a fissure of escape. Through this fissure the intumescent matter, consisting of crystalline particles and vapour intimately mixed, rises and discharges itself, exactly as a mixture of water and steam is discharged from the orifice of Perkins's digester when the cock is suddenly turned.

If the contrary doctrine is to be upheld,—that all lavas have crystallized *after* their emission, during a lengthened state of repose,—how is it possible to account for the fact, that the fragment of liquefied lava which you tear with a hooked rod of iron from the flowing and incandescent source of a current as it issues from the side of a volcano, and which cools and hardens the instant you expose it to the air, is frequently as crystalline in its texture, and moreover contains as many and as perfect large imbedded crystals, as a fragment broken from the interior of the same current, which has cooled with all the slowness required by the hypothesis? Those who can reconcile this fact to the hypothesis in question, will alone continue to disagree with me.

I by no means intend to dispute that all *lavas have crystallized from a state of complete fusion:* on the contrary, I have insisted on it repeatedly; but the above fact, coupled with many others, induces me to believe that their crystallization has been generally effected, not by cooling but by extreme compression; and this *previously* to the emission of the lava into open air, during its confinement at an intense temperature in the volcanic focus within the vent of eruption, under the pressure of the overlying strata. In this position I conceive it may have been in some instances repeatedly liquefied,

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compact mass of felspar or other crystals to an intense temperature under such a compression as should prevent any increase of bulk, and then suddenly relieving or taking away the pressure so as to allow of its instantaneous expansion. But the forces we can operate with, would be probably inadequate to restrain the immense force of expansion which solid bodies acquire by an increase of temperature; and if this difficulty could be got over, another would still remain; viz. that of collecting the aëriform products evolved from the earthy matter as it is rapidly expanded.

perhaps reduced to complete fusion, and resolidified, under new and often varying crystalline forms, by the alternation of circumstances allowing its partial expansion, (as the yielding of the overlying rocks,) with others occasioning the predominance of the enormous force of compression exerted upon it*. Such an effect would be in exact accordance with the result of the experiments of Sir James Hall and Mr. Gregory Watt, in which a crystalline grain was produced, both upon subjecting fused minerals to a high pressure, and by allowing them to *consolidate* slowly and tranquilly.

From a similar misinterpretation (whether intentional or not I will not stop to examine), I have been represented as holding that lava is "cold or thereabouts" as it issues from the source of a volcano. Whereas I have described the heat preserved in *the interior* of the current as often sufficient to sublime the iron of the ferruginous minerals, &c.; but at the same time have given it as my opinion, founded on direct observation as well as reasoning, that upon exposure to the air, or by the formation of fissures, lava parts instantaneously with the greater part of its caloric, in combination with aqueous vapour: and as immense volumes of this vapour are continually discharging themselves from the lava, previous to its protrusion, while it swells up the vent, it must of necessity cool rapidly during its rise, and issue from the opening at a temperature vastly inferior to that which it possessed in its state of subterranean confinement.

This consideration will serve also to explain another objection, which I have heard raised against the theory of volcanic action I have put forth; viz. That if water or aqueous vapour were so intimately combined with every part of the heated mass of lava, it would be blown into the air, as soon as it came on the surface of the earth, in the form of an impalpable powder. But this idea supposes, in the first place, a far greater quantity of vapour than is necessary to give a sufficient degree of mobility to the solid particles of the lava when at an intense temperature, and urged forward by its own weight and an enormous force from behind; which is all I suppose

* See Considerations on Volcanos, pp. 145, 146; and 218, 219.

it to contain at any time. And 2ndly, Those who urge this objection forget, that by the very terms of the theory, all the surplus vapour beyond the quantity required to produce this imperfect fluidity, is *necessarily* discharged in successive volumes, from the lava, as fast as it can be generated, before the emission of this substance from the vent. The fluidity retained by the fine grained lavas after their expulsion on the surface of the earth, requires but the least conceivable quantity of this elastic vehicle; since the extreme comminution of the crystalline particles occasioned by their mutual friction, would alone give them almost as much mobility as they seem to possess. But that they do contain a sufficient quantity of vapour is proved by its escape from every exposed surface of lava, and every fissure formed as it consolidates.

But it may be asked, Since you allow the crystals of lavas to be attenuated to such an extreme degree, as alone to give a considerable fluidity to the mass, why not concede, that this attenuation proceeds to complete fusion, with the finest particles at least, and that these act as a cement to the rest?—I would answer, that I by no means deny this to take place; my position being, that the greater proportion of the constituent crystals of lava were formed before its emission from the volcanic vent. But at the same time I am not inclined to believe in even this partial fusion of lavas; for the experiments of Mr. Gregory Watt have proved most satisfactorily, that to give the stony and crystalline aspect to *melted* lavas, it is absolutely necessary that they should be consolidated *very slowly* and tranquilly, and that, when hardened quickly by immediate exposure to the air, they *invariably* exhibit the glassy texture. Now, as it is but very rarely that basaltic lavas exhibit this glassy texture, even in their finest parts when examined by a microscope;—not even those scoriform masses which have been instantaneously consolidated by contact with the air, or those which were launched out of the midst of the intensely heated bath of lava, and rapidly congealed as they rose into the atmosphere,—I find it difficult to believe that such lavas or their cementing particles *could* have been in a state of complete *fusion* at the time of their congelation.

Wherever the glassy texture exists, there I concede most fully that a more or less complete fusion has taken place; as in the vitreous varnish, or gloss, which is found on the surface of some fine grained lavas and their scoriæ, and in the coating of their vesicles. This pellicle has clearly been fused; and the cause of its fusion I have endeavoured to account for*; (that it *cannot* be owing to rapid congelation is proved from its appearing in the vesicles of the very *inmost parts of the lava*;) but this very circumstance leads me to doubt the fusion of the substance of those scoriæ in which no such gloss is to be perceived, and which yet must have congealed to the full as rapidly as any piece of *the same* lava which, after fusion by the blowpipe or in a furnace, is exposed to the air, and which invariably presents a glassy texture *throughout*.

Some volcanos *have* produced lavas in a state of complete fusion, as that of Bourbon, Monte Bianco at the eastern extremity of Lipari, and others in Teneriffe and Iceland. But in this case the whole substance of the lava-rock retains its glassy texture and fracture, the interior as well as the superficial parts, except that sometimes a vitro-lithoidal aggregation has taken place, producing the globular concretions and testaceous structure of perlite. The chemical constitution of these glassy lava-currents is the same with that of many crystalline and granitoidal trachytes. There can be no reason given why the former masses should have cooled more rapidly than the latter; —what then can account for the difference of their texture, but that they were emitted from the volcano in different conditions, the one in complete fusion like melted glass, the other in a crystalline but intumescent state?

* Volcanos, p. 120.

London,
January 1st, 1826.

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BOOK I.

SKETCH OF THE GEOLOGY OF THE INTERIOR OF FRANCE.

CHAPTER I.

PRIMITIVE AND SECONDARY FORMATIONS.

§ 1. *General Outline.*

IF we imagine a line drawn across France from East to West, passing through Besançon, Nevers, Chateauroux, and Poitiers, it will be divided into two portions, of which the northern may be considered as a vast plain gently sloping in one direction to the Atlantic, and in the other towards the Channel and the low flats of Holland. A similar line commencing at Niort, and continued through Angoulême, Perigeux, Cahors, and Alby, to Carcassone, would cut off another extensive plain stretching towards the base of the Pyrenees and the sandy shores of the Atlantic. To the South of the first line and East of the second, the ground rises with a gradual slope, towards the South-east, so as to form an inclined plane, which progressively acquires a considerable elevation in the Auvergne and Forèz, and a still greater in the Gevaudan and Vivarais, where it reaches the height of 5500 feet above the sea. Here it is abruptly cut down by the deep and wide valley of the Rhone, which divides it from the mountains East of this river in the Departments Drome, Isère, and Hautes Alpes: these preserve nearly the same inclination and a corresponding altitude; so that when the eye overlooks this valley, the inclined plane appears to be prolonged to the Alps themselves, against which those mountains abut. The principal mass of this vast platform is of primitive formation; the secondary sandstone and horizontal limestone of the Perigord, Poitou, Berri, &c., lap over it on the North and West. On the South and East it sinks below the great formation of Jura limestone which constitutes the Lower Cevennes and the bed of the Rhone. Abstraction is here made of the volcanic productions which rise like enormous gibbosities from the higher parts of this elevated plain, and deform its

otherwise nearly uniform surface. It suffers also a considerable depression along the basins of the Loire and Allier, and is deeply furrowed by the channels of the rivers Lot, Trueyre, Dordogne, Sioule, Ardêche, and their tributary torrents. The two former wide valleys have the effect of separating from the main body of the plateau two high embranchments, which parting together from the Mont Lozère, the point at which the primitive rocks attain their greatest elevation*, and forming before they separate the massive table-land of the Haut Vivarais, run nearly in a parallel direction towards the North, gradually decreasing in height and width till they are lost in the great northern plain.

Both basins, viz. of the Loire and Allier, present extensive vestiges of freshwater formations, and another similar deposit occurs near Aurillac (Cantal); partial patches of a very old sandstone and of coal strata occur on two or three points; in all other parts of this great platform the primitive rocks show themselves on the surface, except where they are covered by the products of those numerous volcanos which have burst forth from their interior.

§ 2. *Primitive District.*

Although throughout the whole extent of the elevated region just described, there are frequent irregular alternations of different primitive rocks, yet upon considering it in the whole, it appears divisible into three principal formations: that of Granite occupying the wide band comprised between the Allier and the Rhone; a Gneiss formation dividing the Allier from the Sioule, and continued in the mountains of Cézallier, La Margéride, and part of the Lozère and Cevennes; succeeded by that of Mica-schist which covers and extends over the whole western slope. This division is confirmed by the direction of the different beds or laminæ, which is in general from N. to S. or N.N.E. to S.S.W., and by their very usual dip towards the West. But as it is impossible to assign precise limits to these formations, a perfect granite frequently occurring in the districts of gneiss and mica-schist, and passages into gneiss being as common in that of granite, it will be sufficient to say that felspar predominates along the eastern portion, that this element diminishes and the proportion of mica increases through the middle, and that, on the west, mica prevails to the almost total

* According to Ramond the highest part of this mountain ridge is 1687 metres, or 5535 English feet above the level of the sea.

exclusion of felspar. The Mica-schist is accompanied by Serpentine, which occurs in great abundance at the extremity of the primitive series. Near St. Yriex (Haute Vienne) it occupies a tract of some leagues in extent, and is quarried for marble. At Cahus, Canton de Bretenoux (Lot), as well as in the Departement du Corrèze, it is found exactly at the frontier of the primitive territory. In the Aveyron it appears in two localities; viz. 1. halfway between Rhodèz and Villefranche, and 2. to the east of Firmy. At the last point this rock forms by itself a mountain mass of considerable magnitude. M. Cordier is inclined to consider these different situations as indicating the existence of a large bed of serpentine, accompanying the western base of the primitive mountains in an extent of about fifty leagues*. The coal formation immediately succeeds to this; and it is remarkable that neither clay-slate nor any member of the transition class occurs throughout this district.

Besides the usual elements, different minerals enter occasionally as constituent parts into the composition of the granitic rocks of this country. One of the most remarkable instances of accidental mixtures of this nature is seen in the granite which constitutes a very extensive tract in the Departments Haute Loire and Ardêche, and contains so much Pinite (always granular and amorphous) that I should estimate this ingredient to form at least a third part of the whole rock. It is either generally disseminated in intimate union with the quartz and felspar, or aggregated in globular patches from the size of the first downwards. It is usually accompanied by a small proportion of mica.

Pinite is found also under different circumstances in a rock which occurs near the limits of the mica-schist and gneiss districts, to the north of Clermont. It consists of felspar generally in hexahedral crystals, large rounded grains of quartz, and complete crystals of Pinite, imbedded in a base which appears a finely granular mixture of all three substances, the felspar predominating. The Pinites are generally of a dark green or greenish brown colour, crystallized in hexagonal prisms, of which the angles are flattened so as to give twelve unequal sides to the prism. The felspar is often of a pink colour, the quartz uniformly gray and limpid. I have met with this rock at Manzat, St. Pardoux, and near the Gour de Tàzanà. M. de Laizer has described it as being accompanied by crystallized sulphat of barytes in these spots and at Royat and Champeix; but I could neither succeed in

* Journ. des Mines, tom. ii. p. 345. 1817.

finding any trace of this latter substance in the rock which contains the pinites; nor at any one of the points where veins of crystallized sulphat of barytes occur in the granite, viz. Royat, Champeix, Courtade, La Fontaine des Tambours, or La Four Labro, could I discover any indications of pinites, or hear of their having ever been observed there. The veins of sulphat of barytes are, however, habitually accompanied by a vertical bed of a curious porphyry. The Puy Chateix above Royat is the most marked example of this. The rock of which it is composed presents a base of compact felspar, often extremely siliceous, and occasionally passing into pure quartz; probably it is in general a very fine granular mixture of both these minerals, the *curite* of Daubuisson. It varies in colour from a deep red to a bluish and yellowish white. In this are imbedded large crystals of felspar, sometimes hard and lustrous, oftener completely decomposed; with a few grains of quartz. Occasionally the distinct crystals disappear, the base alone remaining; and finally a passage is effected from this rock into granite, through an apparent breccia of euritic fragments traversed and cemented by heavy spar. The great vertical bed which this rock appears to form, crosses the valley of Royat, and is found again on the opposite side. Its direction is nearly N. and S. From its seeming to be continued immediately below the recent volcanic cone of Graveneire, it is imagined by M. Ramond to be perhaps connected with the cause of that eruption*.

Another modification of granite occurs in the gneiss district near Pont des Eaux, on both banks of the Sioule. It is a compact felspar apparently containing a small proportion of hornblende, fine-grained, extremely fissile

* I am much more inclined to consider it connected in origin with the forcible elevation of the granite platform of which it forms the extreme margin, intervening between it and the inferior bituminous sandstone of the freshwater formation whose strata are there very highly inclined, indeed almost *vertical* where they lean against the porphyry. The indubitable passage of the latter rock into the granite, its fragmented character, as if broken up by the violent friction which must have accompanied the process of elevation, and the sulphat of barytes which has crystallized in the interstices of these fragments, lead to the suspicion that this dyke of porphyry may perhaps bear the same relation to the adjacent granite, as the dykes of pitch-stone to the trachyte which they accompany in the Ponza Isles; as pitchstone is there invariably found to intervene between two contiguous masses of trachyte of different ages, graduating into one of these, and apparently formed by the disintegrating effect of the violent friction sustained by this rock, as it was forcibly protruded in a *nearly* solid and *crystalline* state, through clefts broken across the other.—See Scrope on Volcanos, p. 235: and as yet unpublished Memoir on the Geology of the Ponza Isles, read before the Geological Society in 1823, and preparing for publication in the next Part of its Transactions.

in two directions, breaking easily into small rhomboidal pieces, is generally of a bluish gray or slate colour, and often traversed by numerous laminar ferruginous veins of a rusty yellow. It is sometimes dull and earthy in texture, at others hard and scaly. On some points it lies beneath granite, into which it graduates; the hornblende disappearing, and being replaced by plates of mica and a few grains of quartz. This rock occupies a considerable space, showing itself for the distance of about two miles along the bed of a streamlet, which descends from the Puy de Laschamp. It is universally covered by volcanic products, beneath which it probably prolongs itself to a much greater extent. On the banks of the lake of Aidat, S.W. of Clermont, a belt of rocks appear, formed of felspar and large interlaced crystals of hornblende, with a few grains of quartz; by the diminution of the hornblende and return of the mica, this mixture passes imperceptibly into common granite, from which it seems to be but an accidental deviation. Hornblende also is found in the mica-schist of the department Lot on the boundaries of the primitive district.

In the neighbourhood of Menat (Puy de Dome) the mica-schist graduates into a talcose schist, which occupies however but a small space; the same transition occurs, and in the same manner, at St. Cernin (Cantal) between Mauriac and Aurillac.

These are the only instances I am acquainted with of unusual substances occurring as elements in the granitic rocks of this territory.

Of rarer imbedded minerals I have occasionally observed diverging crystals of actinolite in granite, on the road between St. Hilaire and Combronde (Puy de Dome); large crystals of tourmaline near Issoire, Charade, and St. Saturnin, in the same department, as well as in the granite of the range which separates the beds of the Loire and Allier (Haute Loire).

The felspar of the granitic rocks sometimes appears in large twin crystals. Near Vic le Comte they occur of a rose colour, and as fine as those of Baveno. The quartz also occasionally presents beautiful crystallizations. The amethysts of Le Vernet near Issoire have been long known in commerce.

In metals this primitive district is not exceedingly rich. Iron is very generally disseminated. Many lead mines have been worked at different periods; amongst these one of sulphat of lead at Barbecot near Pont Gibaud, frequently containing silver. At La Rosière in the same neighbourhood is a vein of green arseniated phosphat of lead, accompanied by octohedral fluor spar, green, yellow, and blue. Veins of an argentiferous

galena were also lately worked at the junction of the mica-schist and granite near Villefort (Ardêche), and others in the departments Aveyron and Lot. The granite round Ardes, (Puy de Dome,) and Massiac, (Cantal) is peculiarly rich in antimony; and from hence the most magnificent specimens of this metal in acicular crystals have been extracted. Copper is rare, and few traces of it have been observed. Some veins in the department Aveyron are, however, supposed to have been anciently worked for this metal by the English, when they were in possession of the country.

§ 3. *Secondary Formations.*

The primitive table-land attains its greatest elevation in the Mont Lozère and the Cevennes, where it maintains itself for a considerable distance at more than 5000 feet above the level of the sea. Its descent from thence towards the plains of Languedoc on the south-east, is sudden and rapid, forming a succession of precipices rather than a slope. At the foot of these the primitive rocks cease to show themselves, and are generally succeeded by strata of sandstone, which have a considerable inclination where they rest on the primitive soil, but become more horizontal as they recede from it. This formation would appear decidedly analogous to the variegated sandstone (*Bunter sandstein*), or new red of English geologists, were it not throughout a great extent accompanied by more or less of a sandstone containing large beds of coal, and which seems to warrant its reference to the old red sandstone formation.

The constituent strata of this series on the different points where I had an opportunity of studying it, are; 1. a coarse conglomerate or puddingstone, which always occurs next to the primitive rocks; 2. a sandstone consisting of a detritus of these rocks; 3. micaceous and bituminous shale, containing reeds, bamboos, and other plants of the monocotyledonous class, converted into coal; and 4thly, of coal itself, inclosed between two beds of shale. These strata alternate frequently together, and constitute the coal formation: above this usually appear others of a fine-grained micaceous sandstone with a calcareous cement, green or blue indurated clays, and soft calcareous sandstone, to which succeeds the great formation of Jura limestone.

In the department of L'Aveyron this sandstone incloses beds of gypsum which approaches it still more closely to the variegated sandstone.

The sandstones above described almost every-where intervene between

the primitive plateau, and the secondary limestone strata, which embrace and repose on all sides upon it.

They may be traced uninterruptedly the whole length of the Departments Rhone and Ardêche, across that of Gard, and along the northern limit of the Herault. They then bend back towards the north-west, and traverse the Departments Aveyron, Lot, and Corrèze nearly in a straight line. Through this long extent their breadth varies continually; but is in no part very considerable, as they dip immediately under the Limestone. They rest indiscriminately on Granite, Gneiss, and Mica-Schist. They are not universally accompanied by Coal, but the intervals in which this mineral is wanting are very limited. The principal points on this line where its abundance renders it the object of extraction, are Ville-franche and Chessy, (Rhone), Rive de Gier, (Loire); La Voulte, Prades, and Joyeuse, (Ardêche); Alais and Garges, (Gard); Creuse and Bedarrieux, (Herault); Sansac, Layssac, and Aubin, (Aveyron); Brivezac (Corrèze) &c. &c. In fact the greatest number and some of the richest of the coal mines in France occur along this strip.

Near Argentières the sandstone contains bouldered knots or masses of a rich argentiferous galena, identical with the ore which is extracted from the mica-schist of the mountains above, near Villefort; thus affording a manifest proof that this sandstone has been formed at the expense of the mountains at the base of which it was deposited.

While we are on this topic, it is as well to remark that no fragments of any volcanic rocks, Clinkstone, Trachyte, or Basalt, are found among these conglomerates; which must therefore have been deposited before any of the volcanic eruptions of the mountains they encircle.

The same formation borders the Primitive plateau on the north, and under similar circumstances. Coal is quarried from it on the banks of the Creuse near Gueret (Creuse); at Neris, Montaigu, and Souvigny (Allier); and a short distance south of Charolles (Saone et Loire). It is also observed to penetrate the principal valleys of the plateau to a considerable distance. Examples of this are, the Coal-field of Brassac in the basin of the Allier near Lempde; of St. Etienne in that of the Loire; those of the valleys which descend towards the Lot above Milhau; and those of Bourg Lastic and Bassignac in the basin of the Dordogne. The coal strata of this last locality are remarkable for occurring in a vertical position. Not far from this spot, and near St. Sauve, on the banks of the same river, rise some isolated rocks of a ruinous aspect, which bear the characters of a grey-

wacke schist in most parts, passing at times into a breccia of mica-schist and quartz fragments, and at others into a complete sandstone. They immediately succeed to granite on the East, but are backed by mica-slate on the S. and W. These strata appear to be relics of a mechanical deposit either coeval with or anterior to that of the old Sandstone. In the same class perhaps should be ranged the coarse-grained Sandstone occurring in a sort of basin on the borders of the Allier, at Vie le Comte, and Coude, (Puy de Dome,) as well as at Nonnette, in the same department. It is in general formed of large crystals of felspar, the angles of which are frequently uninjured, grains of quartz, and a small proportion of mica; sometimes these ingredients seem to adhere by mere pressure; at others are agglutinated by a siliceous cement. Not unfrequently this mixture so much resembles a coarse granite as to deceive an inexperienced observer. Occasionally it changes to a pudding-stone. No clayey particles are discoverable in it; but the felspar crystals are often decomposed into a kaolin. This rock is extremely hard, and in use for mill-stones. Vertical fissures traverse and divide it into rude quadrangular pillars. Of precisely the same nature is a sandstone found in a similar situation on the banks of the Loire, at Brives and Le Chartreux, near Le Puy (Haute Loire), as well as at Blaves in the same neighbourhood, where it is quarried for building. The siliceous cement which penetrates this rock has sometimes formed in it veins or nodular masses of a dark gray quartz, and these are what the fertile imagination of M. Faujas de St. Fond converted into portions of Basalt preserved by a miracle without injury from the decomposition which had metamorphosed the rest of the mass into a *pseudo-granite**. This rock has no apparent relation to the freshwater clays and marls which rest on it at both places, but is on the contrary closely connected with the granite beneath, from the detritus of which it has clearly been derived.

It must not be confounded with other sandstones in the same neighbourhood, which evince their more recent formation by a clayey or calcareous cement.

Upon the whole we seem authorised to conclude from these observations, that the primitive mountain district of the interior of France is completely incircled and enveloped by new red Sandstone, accompanied at intervals by coal-fields, which, whether to be reckoned subordinate or not to this formation, always occur *below*, never above it.

* "Volcans Etents du Vivarais et Velay"—fol.

This narrow slip is soon in turn concealed by a massive formation of Jura Limestone, to the West, South, and East of the primitive plateau. It is now, I believe, generally recognised that the limestone which succeeds to it on the North, forming part of Poitou, the Berri, &c., and supporting the chalk of Touraine and Champagne, belongs also to the same epoch, viz. that of the great oolitic series.

This Limestone to the South of the primitive platform composes the greater part of the department of the Aveyron, and a large proportion of the surface of those of Lozère, Gard and Ardêche. This district appears once to have formed a vast elevated platform, sloping gradually from the primitive range towards the S.W. But having been since intersected by the channels of numerous rivers and their tributary torrents, it exhibits at present a series of extensive flat-topped hills bounded by perpendicular cliffs 600 or 800 feet high; a peculiarity of feature which often distinguishes the Jura Limestone formation. These plateaux are called "*Causses*" in the vernacular dialect. They have a dreary and desert aspect, from the monotony of their shape, and the barren and rocky character of their surface and sides. The valleys which separate them are sometimes of considerable width, but deep and narrow fissure-like gorges predominate, particularly where the rock is hardest, and the clays and shales are absent.

Their strata are nearly horizontal, but in the vicinity of the primitive mountains dip at an angle of from 10° to 15° towards the S. and S.W. They vary in thickness from half a foot to twenty or more. The colour of the Limestone is a bluish gray, more or less deep; it assumes by external decomposition an ochreous yellow hue. The fracture is conchoidal; texture compact, with occasional patches of a coarse crystalline grain. Some strata are stained of a red colour, and traversed by veins of calcareous spar so as to form a handsome marble.

Interstratified with the limestone are beds often of considerable thickness of blue marls and clay, sometimes bituminous, often passing into hard foliated clay, or *shale*, generally abounding in pyrites which have often taken the mould of the organic remains enveloped in the clay. These are Ammonites, and Belemnites of a large size, Gryphites, Terebratulæ, Echini, Arcæ, Neritæ, Pectines, and other Lias fossils. The same fossils occur in the compact limestone strata, as well as Iron pyrites in dodecahedral crystals or reniform nodules with a radiated structure. The shells are observed to be usually disposed in families, *i. e.* one stratum will contain vast num-

bers of pectines, another in a different locality an assemblage of gryphites, or ammonites.

The limestone west of the primitive table-land incloses rich coal-beds, which are worked at Milhau (Aveyron) and other spots; and in one instance, not far from Figeac (Lot), on the limits of the secondary district, a thick stratum of Calamine. Galena also is met with on some points of this formation, as at St. Sauveur, Gatuzières, and Allenc, (Lozère). It occurs both in nodules and veins; these latter usually penetrate the underlying mica-slate or granite as well as the limestone.

If this formation is to be referred to the oolitic series, of which, from its reposing on the new red sandstone, and its characteristic fossils, there can, I think, be no doubt, the highly crystalline nature of its limestone strata, and the seeming want of any true oolitic beds are worthy of remark.

CHAPTER II.

FRESHWATER FORMATIONS.

§ 1. *General Remarks on Freshwater Formations.*

THE fact of the existence of freshwater formations, first decidedly announced in the Memoir of MM. Brongniart and Cuvier, read to the Institute in 1808, has, notwithstanding the opposition this opinion at first excited, received such complete confirmation by the discovery of similar deposits in numerous points of France, England, Spain, Germany, and Italy, that it may now be considered as satisfactorily established; and from the great apparent resemblance and peculiar features of these formations wherever they occur, we may hope before long to have their characters laid down with a precision which will enable them to be recognised and distinguished with far greater facility than can be expected from the ever-varying nature of marine sediments. The division that seems best to accord with our actual knowledge of such formations, is that proposed by M. Marcel de Serres, who, in a memoir in the *Journal de Physique*, 1818, separated them into four classes, referable to four distinct æras. These it may not be amiss to recapitulate in this place. They are,—commencing with the most ancient,—

1st, That of the Lignites, accompanied by bituminous shales containing freshwater shells. It is found in connexion with the limestone of all ages up to the chalk inclusively. And it may be as well to remark, that it appears in many different points upon the Jura or oolitic limestones of the Basin of the Rhone, from Crest (Isère) southward to near Béziers (Hérault).

2dly, (1st of MM. Cuvier and Brongniart) characterized by gypsum with bones of mammiferæ, and white marls with shells.

3dly, (2d of MM. Cuvier and Brongniart). That which has been most frequently observed, is generally relative in extent to some containing cavity, incloses more river than land shells, which are ordinarily of the same

genera as those found in our present marshes, but of different and unknown species. This formation consists principally of two different rocks, described by Brongniart under the titles of *Calcaire d'eau douce*, and *Calcaire siliceux*.

4thly, The 4th division established by M. de Serres from the result of his own observations, contains a limestone which frequently puts on a stalagmitic appearance, and though generally soft is sometimes sufficiently hard to be used for building and even paving; incloses shells of the same species as those which actually inhabit our stagnant waters or rivers, accompanied by numerous fruits, leaves, and branches of trees, apparently referable to those actually growing on our continent, casts of insects, &c. This last class would seem to comprehend the calcareous tufas and travertines that have been so largely deposited in Italy and elsewhere, and the formation of which is still going on under our eyes*.

Having briefly premised these remarks, I shall go on to describe those portions of freshwater formations which occur in Auvergne and Velay, as far as the extent of my observations will allow me.

I have mentioned above that they are found to occupy three different districts on the primitive plateau, appearing to have been deposited in as many distinct and independent basins. M. Omalius, in supposing the formation of Aurillac to have been a continuation of that of Auvergne, previous to the volcanic eruptions by which the intermediate mountain of the Cantal was raised, must have overlooked the uninterrupted *primitive* barrier, which unites the Montagnes de Cézallier with those of La Margeride, and may be traced along the deep channels of the Alagnon, and other torrents descending from it into the Allier, as well as on the western slope of the Cantal at Thiezac, &c., uniformly preserving an elevation much superior to that attained by the freshwater limestone on either side. It is not indeed very improbable that this primitive escarpment has been *elevated since* the deposition of the freshwater strata. But had M. Omalius contemplated such a fact, it is to be presumed he would not have passed it in silence.

§ 2. *Freshwater Formation of the Limagne.*

That portion of the valley-plain of the Allier which lies within the department of the Puy de Dome, formerly went by the name of the Limagne

* See a Memoir of M. J. J. Omalius d'Halloy, *Journal des Mines*, 1812. p. 403. no. 192; and Brocchi Cat. Rag. di Rocce, *passim*.

d'Auvergne. Its fertility, which gained it the title of the garden of France, is chiefly attributable to the detritus of volcanic rocks, entering for a considerable share into the composition of its soil. It is inclosed by two parallel primitive ranges; that of the Forèz, which divides the waters of the Loire and Allier, on the east; and that of the Basse Auvergne, or Monts Domes, which separates the latter river from the Sioule, on the west. Its average breadth is about 20 miles, and its elevation between 1000 and 1300 feet from the sea. The surface of this plain is an alluvium, principally consisting of granitic and basaltic boulders; the substratum is generally calcareous. Many hills of this nature rise from it to different elevations, and the Allier flows over limestone strata wherever its bed has not been excavated through the lowest of these into the rocks below. This case has, however, occurred between Issoire and Les Martres de Vayres, where for a considerable distance, the river runs in a narrow channel over granite, and occasionally over the siliceous sandstone mentioned above. The valley is narrowed on this spot, between an embranchment of the primitive chain separating the Dore and Allier on the east; and on the other side a series of high basaltic plateaux resting upon calcareous strata, and projected like so many promontories into the plain, from the lofty mass of the Mont Dor. Higher up it widens again, the granite recedes and gives place again to limestone, which reaches to the coal-field of Brassac.

M. de Ramond very justly describes the hills formed of calcareous and alluvial deposits, which are frequent throughout the plain of the Limagne, but more particularly near the primitive heights on either side, as "scattered relics of a series of beds which once covered the actual soil, and constituted an ancient plain much above the level of the present one."

Many of these fragments have been protected from the destruction which has swept away the greater part of the formation, by cappings of basalt. Some, however, owe their preservation to horizontal strata of a hard and durable limestone, described hereafter, which cover them in the same manner. These hills are seldom found in direct union with the primitive rocks, but are in general separated from them by shallow transversal valleys, so that the junction of the two formations is not often perceptible.

The base of the western granitic range is in most parts clothed by a soft calcareous sandstone, composed of particles of quartz and felspar very little water-worn, with some bouldered pebbles and primitive fragments, united by a calcareous cement. Its strata are irregular, and generally inclined at a very considerable angle, sometimes indeed approaching to a vertical posi-

tion. So much bitumen is contained in this rock that the rays of the sun cause it to exude in large viscid drops; and attempts have been made at different times, but without much success, to bring this into use for œconomical purposes, as a coating for roofs and terraces.

This seems to be the first term of the calcareous formation; the remainder, as far as it can be ascertained from various lateral sections of the hills which it composes, exhibited in ravines furrowing their sides, consists of a white marly limestone, brittle, and soft, disposed in thin horizontal strata, alternating, when near the granite, with beds of a gravelly sand the detritus of primitive rocks, and with strata of a calcareo-siliceous stalagmitic concretion. These last contain, or rather are principally composed of that curious fossil first noticed by M. Bosc*, and named by him *Indusia tubulata*. They are universally found in single stony beds, varying in thickness from 10 or 12 feet to 1. In those which are thinnest the stratum is often interrupted, or continued in separate nodular blocks imbedded in a loose sand, evidently the result of the same concretionary action, which, where the siliceous matter was more abundant, produced an entire stratum. The upper surface of these blocks and of each stratum is moulded into fantastic conoidal or mammillated protuberances of all sizes, and their fracture exhibits concentric lines parallel to the rounded forms of the exterior, just like those of an irregular stalagmite. The nucleus of each protuberance is often, but not always, formed of one or many of those tubular fossils described by M. Bosc. They are from one to two inches in length, closed at one end by a hemispherical concavity, and placed, with respect to one another, either parallel, or interlaced in all directions. Some are immediately surrounded and cemented together by the stalactitic substance; others by innumerable multitudes of casts of minute shells, chiefly the *Bulimus atomus* of Brongniart, arranged with some symmetry round each tube, and pressing closely on one another†.

* Journal des Mines, tom. xvii. no. 101. p. 397.

† More than a hundred of these shells may be counted on each tube, and ten or twelve tubes are constantly packed together within the space of a cubic inch. If then we consider that *repeated* strata averaging five or six feet in thickness, and almost entirely composed of these tubes, appear once to have extended over the whole plain of the Limagne, occupying a surface of many hundred square miles, we shall arrive at an imperfect idea of the countless myriads of minute beings belonging to a single species of Mollusca which have lived and died in turn within the bosom of this once extensive lake! Such a reflection, like many others of a similar stamp which occur at every step to the investigator of Nature, recalls that trite but true French saying, "Dieu est grand dans les grandes choses, mais il est encore plus grand dans les petites."

The tubes are not always regularly cylindrical, but appear often bent in at the sides, and though generally empty, are coated internally by the same calcareous infiltration which connects the shells and tubes together, and incloses the whole in a series of concentric layers. I have found the same substance enveloping in the same manner water-worn fragments of granite, mica-schist, and even of the identical rock itself, but always in the immediate neighbourhood of the primitive range. As we recede from this, the gravelly sand which is associated with the stratum disappears, and its substance becomes more completely calcareous.

All the numerous specimens I have found on different and very distant points of the Basin agree perfectly with the origin assigned to them by M. Bosc; viz. that of having been the Indusiæ of the larva of some species of Phryganea. It is well known that certain varieties of this insect habitually clothe their bodies with a cylindrical case, formed entirely of numerous minute river shells of some single species, helices, mytili, &c., united by glutinous filaments, and disposed in some sort of order around. These habitations are quitted when the insect's metamorphosis is completed; and on the banks of rivers or marshes frequented by them, groups of such empty cases may be observed, arranged much in the same manner as those under discussion appear to have been when the calcareous matter incrusted them.

At times in place of the tubes appear numerous small parallel filaments, probably twigs or moss, closely packed together; and occasionally an aggregation of minute oolitic grains.

I have remarked many repeated strata with these characters, and alternating with the marly limestone beds, on Gergovia, above Romagnat, where the upper one supports a basaltic plateau; at the Puys de Jussat, de Girou, de Monton; on the southern side of the Montagne de la Serre near Chadrat, where they rest immediately against the granite; at the Puy de Dallet; at Mont Chagny, Mont Jughat, and Les Côtes, near Clermont, as well as on other points of the freshwater basin, throughout which they seem to have been generally but irregularly formed.

At Mont Jughat some of these beds lose their stalagmitic character, and appear as a compact earthy limestone of an ochreous yellow colour. They contain large shells resembling the *Helix Ramondi* of Brongniart, but have six whorls to their spire instead of four. They are traversed by fine veins of semi-opal.

In some parts of the Basin, in place of the concretionary deposits, thick strata of a compact fine-grained and highly siliceous limestone of a yellowish gray colour and a conchoidal fracture, breaking into sharp fragments

like flint, are found alternating with the soft or marly variety. At the Chox* de Rignat near Crest, these are less siliceous, resemble the lithographic stone of Chateau-roux, and contain impressions of the *Potamides Lamarckii.* At Nonnette the same shells accompanied by the *Helix Cocquii* occur in great profusion in similar beds, which are quarried as marble for ornamental purposes; the casts of the shells being filled with calcareous spar. The plain stretching from the foot of the Puy St. Sandoux to the Allier, on which stand the communes of Authèzat and Plauzat, is entirely formed of horizontal beds of limestone inclosing *Planorbes* and *Limnei.*

In general the strata which contain shells are more or less impregnated with silex; while the thick beds of white soft and marly limestone are free from testaceous remains, but envelope here and there scattered bones which appear to have belonged to aquatic birds. I have found such at Romagnat, and between Pont du Chateau and Lempde†. The fissures of this limestone are occasionally filled with crystals of selenite. These are so abundant as to be extracted for commerce at the Puys de Coran, de Millefleur, and the Butte de Monpensier.

On the whole, the strata which serve most particularly to characterize this freshwater formation, are those containing the *Indusia tubulata:* and as besides the spots already mentioned in the vicinity of Clermont, I have found these at Davayat near Riom, at Aigueperse, Gannat, Mayet d'Ecole, in short generally throughout the whole length of the Limagne, and that according to MM. Bosc and Omalius d'Halloy they occur at St. Geraud le Puy, between Jaligny and La Palisse, at Pont Barraud, &c.,—it would appear that this same series of sedimental deposits once extended over the whole plain of the Allier as far as Moulins, perhaps to the junction of this river with the Loire.

* Every mountain or hill approaching to a conical form is called *Puy* in the Patois of Auvergne; those that are long and flat at the top, *Chox.*

† Since the time of my quitting Auvergne, a great number of fossil bones have been found in these marly limestone strata. The Mont Perrier near Issoire is the richest locality; at least 30 different species of *quadrupeds*, mostly new, having been found there, including the mastodon, elephant, rhinoceros, hippopotamus, tapir, bear, hyena, varieties of deer, beaver, fox, cat, &c From the limestone of Gergovia, which as well as the Mont Perrier lies under a massive current of basalt, 4 species have been extracted; viz. 2 species of birds, 1 anaplotherium, 1 reptile. The limestone of the vicinity of Volvic has furnished 2 species of anaplotherium, 2 of palæotherium, 2 graminivorous animals, 2 carnivorous, and 2 reptiles.—See Bulletin des Sciences, sect. 2. vol. vi.

Further researches will it is to be hoped be made, and will no doubt produce before long a complete *Fauna* of this district at the æra of its freshwater lake.

The thickness and absolute elevation of this formation are alike remarkable. At the Puy de Dallet, strata containing the *Indusia tubulata* are found nearly 900 feet above the bed of the Allier below, which is worn out of a similar stratum inclosing the *Helix Ramondi* and *Planorbis Cornu*. The village of Opme, on one of those fragments of the former bed of the lake the surface of which has been secured by a protecting stratum of the same stalactitic limestone, and perhaps originally by a coating of basalt, since some small columnar groups still remain upon it, stands at an absolute elevation of 2212 feet. At the *Puy Girou* close to the line of junction of the freshwater limestone and primitive rocks, the former supports a conical group of basaltic columns at the height of 2500 feet. Between this point and the calcareous bed of the Allier at Pont du Chateau, there is a difference of level of 1500 feet.

It is difficult to imagine that the low hills of secondary limestone which now remain between Moulins and Nevers, and those over which the Canal du Centre is conducted, could at any former time have reached the height necessary for their forming a barrier to a body of water which was depositing its sediments in tranquillity at an elevation of 2500 feet above the sea. And yet it would be still more staggering to look for this barrier in the transition rocks which appear once to have dammed up the waters of the Loire between Angers and Nantes. Partial and smaller basins are out of the question. Every observation leads to the conclusion that the formation of freshwater limestone in the basin of the Allier was single and uninterrupted from Brioude at least to Moulins.

The only hypothesis therefore, which seems capable of accounting for this extraordinary difference of level in parts of the same continuous formation, is the supposition that a large portion of it has been forcibly elevated far above the level at which it was originally deposited in the bosom of a great lake covering a large surface of the centre of France, by the general, and perhaps gradual, upheaving of the mass of primitive rock which supports the elevated portions. In other words, that *the great mountainous platform of Central France*, which we are now describing, *has risen from* 1500 *to* 2000 *feet, since the æra of the deposition of the freshwater formation.*

I have not yet adverted to a fact connected with the freshwater formation of the Limagne which gives it an additional interest; I mean its alternation and intermixture with volcanic products. The first circumstance occurs in the Montagne de Gergovia, and will be described more fully when we are on the subject of the Basaltic plateaux; the latter, viz. the intimate mix-

ture of volcanic substances with the calcareous sediment may be perhaps as well circumstantiated in this place, particularly since the facts observed have little or no connexion with any other of the volcanic phænomena presented by this country.

This union shows itself in two very different modes. In the one, fragments of Basalt, Scoriæ, and a few crystals of Augite appear scattered sometimes rarely, oftener plentifully, through strata of limestone which preserve their horizontality, and are in no way disturbed. In the other, the intermixture of the same substances appears to have been violent and tumultuous, no traces of stratification remain, the volcanic and calcareous particles are more intimately blended, and the former are more numerous, frequently so much so as to pass into a complete Basalt.

A remarkable example of the first case may be seen on the banks of the Allier immediately above Pont du Chateau. The river here flows at the foot of a line of Cliff which it is continually undermining, and thus exposes a regular vertical section of it, rather more than 100 feet in height. (See Plate I.)

The upper surface of the cliff is horizontal, and formed to the depth of 8 or 10 feet of a bed of boulders exactly the same as those which the river still heaps up on its banks below. Beneath this the strata are not completely horizontal, but have a slight curve, which facilitates their examination by bringing them all in turn nearly to the level of the river. Commencing from the upper bed of alluvial matter they consist of,

1st. Numerous strata from three or four feet to a few inches in thickness, of a compact limestone, which varies in colour from brownish yellow to bluish gray, and incloses small angular fragments of basalt slightly porous, and a few crystals of augite. In each stratum the fragments are found only near the lower surface, and arranged according to their respective gravities, the largest at the bottom, and the rest diminishing in size in proportion to their distance from thence. That part of the limestone which contains no visible fragments, appears to owe its different shades of colouring to a greater or less admixture of very fine basaltic particles.

2ndly. A single stratum 10 inches in thickness, of a very compact, hard, and fine-grained limestone, with a conchoidal fracture, of a deep bluish black or plum colour,—no contained fragments.

3dly. Many strata of the soft white and foliated marly limestone, the same which is so general throughout the Limagne, wholly free from either volcanic fragments or organic remains.

4thly. A bed about 4 feet thick of a coarse-grained limestone of an

ochreous yellow colour; fracture dull and earthy, with irregular tubular cavities, and inclosing the casts of numerous large shells of the species *Helix Ramondi* and *Planorbis Cornu;* the testaceous part being generally replaced by bitumen which occupies and exudes from other cavities and fissures of the stone.

5thly. A repetition of similar strata to those above (1), containing fragments of Basalt, &c.

The strata interspersed with volcanic matter are perfectly parallel to those that are free from it, have precisely the same structure, and present all the characters of a sediment slowly and tranquilly deposited by a body of water into which repeated showers of volcanic ashes and fragments were projected by some neighbouring volcano.

Examples of an admixture of the same substances in a different manner may be observed on many independent points of the plain, but particularly at Verthaison, Cour-cour, Pont du Chateau, and the Puys Marmant, de Crouelle, and de la Poix.

Here are hills, some of very considerable magnitude, formed of a rock which varies by gradual and frequent transitions from a limestone impregnated more or less with volcanic particles, which affect its colour and aspect, to a breccia, both fine and coarse, of volcanic and limestone fragments, to a peperino * of scoriæ, and pieces of Basalt, cemented by calcareous spar, and finally to a compact Basalt. No traces of arrangement or stratification are visible; all is confusion, and each of these different hills forcibly suggests the idea that it owes its formation to a subaqueous volcanic eruption while the calcareous sediments were yet soft. The occurrence of eruptions

* In giving the name of *peperino* to a volcanic conglomerate consisting of fragments of basalt and scoriæ, without pumice, tufa, or any trachytic matter, united either by simple adhesion or a calcareous or argillaceous cement, I follow the Italian geologists, who have continued this trivial term to a similar rock, which also, like that under consideration, occasionally contains fragments of limestone and primitive rocks, bituminized wood, &c., &c.—Vid. *Brocchi* Catalogo ragionato di Rocce, pp. 45, 47.

There exists the strongest analogy between the calcareous peperino of the Limagne and that of the Vicentin, the latter being without doubt the result of volcanic eruptions breaking forth from the bottom of the *sea*, in which vast masses of calcareous matter (part of the tertiary formation) lay in a pulpy unconsolidated state; the latter of eruptions through a similar mass, the deposit of a *freshwater* lake. The great variety of rare and beautiful crystallizations to which this violent mixture of calcareous matter with incandescent lava has given rise in both localities, is remarkable. Mesotype, stilbite, arragonite, chalcedony, and numerous forms of calcareous spar abound in the drusy cavities and veins of both these conglomerates.

during even the early stages of the limestone formation is proved by the strata inclosing fragments of lava described above, and which according to all appearance form the basis of the Puy de Dallet. The volcanic substances so thickly mingled with the calcareous matter in these beds seem to have given them a superior degree of solidity to the remainder of the formation, and enabled them to resist more successfully the agents of destruction.

It is from a hill composed entirely of calcareous peperino on which stands the village of Verthaison that some of the finest radiated arragonite of Auvergne is extracted. It occurs in veins varying from a thickness of 10 or 12 inches to that of paper. They intersect the rock in such numbers as frequently to give it a coarse reticulated appearance. From hence a range of hill consisting solely of the same rock extends about 2 miles towards the South. Above the village of Chauriat it presents a very compact and hard stone, composed of small unequal fragments of augitic basalt firmly united by a fine and rare cement of calcareous spar. It is difficult while examining this rock, to believe that the Basaltic parts are in reality mere fragments, and the impression is strongly excited that its peculiar structure is owing to a separation of dissimilar substances during the consolidation of a lava which by some mechanical cause had been universally penetrated with calcareous matter *.

La Montagne de Cour-cour, an insulated hill of considerable size rising alone from the plain near Beauregard, is of the same nature. The peperino here is traversed by irregular venous masses of dark gray Basalt. Arragonite is not so abundant as at Verthaison.

The Puy de Marmont rises on the other side of the Allier above Vayre, the first relay on the posting-road from Clermont to Le Puy. This hill is connected by the base with another of a rather larger size on which stands the town of Monton, but differs from it in substance. Its principal component rock is like those already described, a peperino of basaltic fragments, small scoriæ, and fine volcanic detritus mingled with fragments of limestone of various sizes and united by a calcareous cement. On the western side of the hill fronting the Puy de Monton the limestone fragments predominate; the opposite or eastern face consists of an amorphous mass of basalt, hard, solid, and of a dark bluish gray colour. Parts of this rock are amyg-

* The calcareous peperino of the Vicentine (Montecchio Maggiore), exhibits some very similar mixtures of basalt and calcareous spar, which it is difficult to refer decidedly either to the conglomerate or the solid lava-rock.

daloidal, being thickly larded with globules of compact radiated mesotype; this mineral has evidently occupied the vesicles formerly existing in the stone. Where the cavity is of a considerable size, it is not filled throughout with the zeolite; but a nest or hollow pouch appears, lined with the most brilliant crystals. These are too well known in all mineralogical collections to require a description here. That variety is most common which consists of radiated groups of large quadrilateral prisms terminated by an obtuse pyramid whose faces correspond with the sides of the prism. Numerous capillary crystals resembling the finest spun glass are sometimes joined with these, but more frequently occupy separate cavities. The same crystallizations are found in cavities of the peperino as well as of the basalt,—others present different beautiful varieties of calcareous spar.

The peperino of Pont du Chateau is equally rich in rare and splendid specimens, and unhappily Auvergne has been but too often visited merely for the purpose of enriching a collection. Few cabinets are without its finest minerals; but fewer naturalists are acquainted with its most interesting geology.

The rock upon which stands part of the town, consists of a peperino similar in its usual characters to those already described, and traversed by fissures from which a prodigious abundance of viscid bitumen exudes spontaneously. The cheeks of these clefts are frequently lined with mammillæ of chalcedony, and from these occasionally spring the most graceful groups of small rock-crystals diverging from a central point, and spread out with the regularity of the petals of a marigold. The union within a single specimen of the smallest dimensions, of volcanic scoriæ, limestone, chalcedony, rock-crystal, and bitumen, is singular.

Some of the upper parts of this rock present a spheroidal structure, similar to what often occurs in basalt. The spheroids are from two feet to a few inches in diameter. They exfoliate by decomposition in concentric coats like those of an onion. This configuration appears remarkable in a conglomerate. A compact fine-grained and siliceous limestone free from visible basaltic particles, though of a light brown colour, pierces through this rock occasionally from below, and mixes intimately with it at the line of contact.

The Puys de la Poix and de Cruel, and the low hill on which Clermont stands *, consist of a similar species of peperino bearing equally the ap-

* Nos. 90, 89, and 88 in our map of the Monts Domes.

pearance of a violent and intimate union of volcanic fragmentary matter with limestone while yet unhardened. They inclose indefinite masses and veins of pure limestone, some bituminized wood, chalcedony, and bitumen. The latter substance formerly exuded in great abundance from the Puy de la Poix.

At the northern base of the hill upon which Clermont is built, rises a spring, the water of which is impregnated by means of its carbonic acid, with so large a proportion of carbonat of lime, which it deposits on issuing into the air, that its incrustations have formed an elevated natural aqueduct 240 feet in length, and terminating in an arch thrown across the stream it originally flowed into, 16 feet high and 12 wide. Near it are the rudiments of a similar arch, the construction of which is still going on, and aptly illustrates the formation of the other. Like many other similar incrusting springs in different countries, it has been turned into a source of emolument by the proprietor, who breaks the fall of the water in such a manner that its stony particles may be deposited on various natural objects exposed to its spray. At the time of my visit the stuffed skins of a horse and a cow were undergoing this petrifying process, as well as the usual proportion of birds, fruit, flowers, &c.

There are two other springs in Auvergne possessed in a high degree of the same qualities. One at Chalucet near Pont-gibaud, the other called La Fontaine de Rambon on the banks of the Crouze near St. Floret. On both sides of this river, and for a considerable distance down the gorge it flows in, are seen colossal fragments of calcareous tufa, which by their position prove this mineral spring to have once erected a bridge similar to that of St. Alyre at Clermont, but exceeding it prodigiously in dimensions, and probably choking up the whole valley, since the source itself is elevated more than 100 feet above the river.

It is worthy of remark that these three springs, whose deposits are, except in a greater or less proportion of iron, exactly alike, rise from rocks of different kinds: the first from a calcareous peperino; the second from the foot of a regular volcanic cone, at least 20 miles from any calcareous rock; the third from granite. It is apparent from this that all have their origin in or below the primitive rocks which form the basis of the whole territory, and which include or cover the volcanic focus whence in reality these mineral springs in all probability ultimately derive. The same observation may be made, and the same origin supposed, with respect to the many *thermal* sources which occur on various points of the platform, springing indifferently from primitive or volcanic rocks; as at Mont Dor les Bains, La Bour-

boule, Senecterre, Chatelguyon, Gimeaux, Neris, Vichy, Vic en Carladèz, Chaudesaigues, &c.

§ 3. *Cantal.*

It would appear from the above remarks that the freshwater formation of the Limagne corresponds with the upper freshwater formation of the Paris basin, and belongs to the third division of M. de Serres's classification; and MM. Brongniart and Omalius d'Halloy unite in placing it there. That which occurs in the vicinity of Aurillac must be referred to the same epoch.

The limits of the basin in which it was deposited are with difficulty to be distinguished, owing to the superposition of an immense volcanic formation. It is found, however, universally beneath this, wherever any torrent has disclosed the inferior strata, within a space limited by lines passing through Jussac, Vic en Carladèz, La Capelle, Mur de Barrèz, and Panet.

It consists of a marly limestone in horizontal strata alternating with a few of clay and clayey marl, and traversed by parallel beds of flint either in continuous zones or flattish nodular masses. The silex and limestone graduate into each other. The former is yellowish brown or grayish blue, sometimes ribboned with alternate stripes of these colours. It frequently has an oily or resinous lustre, which makes it approach to agate. The limestone, where it is pure from flint, is white or yellowish white, of an earthy and coarse fracture, full of shapeless tubular cavities, and, occasionally of small filamentous perforations, such as would be left by reeds, grasses, or other weeds, enveloped as they grew by a calcareous sediment. It incloses also numerous freshwater shells, the Potamides Lamarckii, Limneus Cornu, Limneus inflatus, Planorbis rotundatus, and Planorbis Cornu, with some other exceedingly minute testaceæ, and that curious little fossil seed-vessel the Gyrogonites. The interior of those shells which occur in the silex or siliceous limestone is sometimes lined with mammillated chalcedony, while the testaceous part remains composed of carbonate of lime. At others the shell itself is of a transparent horny flint, and the interior a siliceous limestone.

This formation rests immediately upon mica-schist, which is visible at Thièzac and along the banks of the Goul near Taussac Mur de Barrèz and La Capelle. It supports in turn a mass of volcanic breccia with interjacent beds of trachyte and basalt. There are appearances between Aurillac and Polminhac of its having been also in part confusedly deposited *upon* those substances.

§ 4. *Freshwater Formation of the Haute Loire.*

The freshwater formation of the Basin of the Loire which surrounds Le Puy, the capital of the department of the Haute Loire, differs considerably from the two above described, and contains a series of beds which perhaps may be conceived to represent all the three successive freshwater formations of the Paris basin, their intervening marine beds being here of course absent.

Like that of the Cantal it has been overwhelmed by prodigious and repeated accumulations of volcanic products, which load it with a massive covering frequently between three and four hundred feet in thickness. It is only therefore at the sides of the deep and water-worn ravines which furrow this tabular surface, that any glimpse can in general be obtained of the limestone, marls, clays, and sand supporting it. The river Borne, however, towards its confluence with the Loire, and the Loire itself, have somewhat wider channels, allowing an ampler view of the strata through which they have been excavated *.

For these reasons it is difficult to determine with accuracy the limits of the freshwater basin: by tracing, however, its deposits up the beds of the neighbouring torrents, they may be ascertained to extend on the west as far as the foot of that granitic chain which separates the waters of the Loire and Allier. The rise of the primitive platform towards the Haut Vivarais evidently bounded it on the south; and some irregular embranchments from the primitive heights of Les Bouttières and La Chaise Dieu on the east and north. One of these embranchments indeed stretches entirely across the formation and divides it into two, cutting off the small basin of Emblavès from the upper and larger one in which lies the town of Le Puy. The river Loire passes from the latter basin into that of Emblavès through the narrow, deep, and sinuous gorge of La Voute, and finally issues from this again by means of the equally difficult defile of Chamalières, an outlet which appears to have been at some distant epoch blocked up by a massive current of clinkstone.

The strata which constitute this formation rest in general immediately on the granite, which appears on all sides to have formed the margin of the lakes in the bosom of which they were deposited. On a very few points a remnant of secondary sandstone intervenes. The lowest beds which we

* See the Panoramic View of the Environs of Le Puy. Plate XII.

must refer to the freshwater series consist generally of a clayey sand of a reddish colour, sometimes variegated, the mere gravelly detritus of the granite on which it reposes. These, which occupy the situation of the bituminous sandstone of the Limagne basin, support numerous beds of a white and friable marl, alternating at first with others of a light greenish or bluish marly clay. In neither, I believe, have organic remains ever been discovered. Many beds of this clay are used for pottery. Some are thickly veined with calcareous spar, sometimes fibrous, and arragonite. The upper part of the series consists almost wholly of marly limestone, which on some points, particularly in the vicinity of, or where covered by, basalt or clinkstone, becomes highly siliceous, incloses layers of flint passing into semi-opal (silex resinite), and even some thick beds entirely composed of the latter substance. At St. Pierre Eynac these siliceous strata support the powerful clinkstone mass of Montplaux. The whole series may perhaps be supposed analogous to the Plastic clay of the Paris basin.

These clayey marls towards the middle of the basin of Le Puy begin to alternate with beds of gypsum. Three of these are sufficiently rich to be worked for agricultural uses, varying from 2 to 15 inches in thickness. They contain a few shells of the genera Limneus and Bulimus, and from one of them M. Bertrand Roux has extracted the entire lower jaw of a species of Palæotherium, which certainly tends to confirm the analogy of this formation to that of the Parisian gypsum. The base of the Rocher Corneille, a conical eminence half incircled by the town of Le Puy and crowned by an enormous and grotesque rock of volcanic breccia, contains the principal quarries. The gypsum occurs either fibrous, or compact and scaly, approaching to the saccharoidal. Vertical veins of delicately fibrous selenite also occur at intervals intersecting the whole series of beds. It is observable that the gypsum has been on many points dissolved and carried away by the infiltration of rain water, the accompanying strata of marl collapsing together. The springs which issue from these hills are by this means highly charged with sulphate of lime.

Above the clayey marls with gypsum occurs a series of strata of calcareous and foliated marls alternating with others of a grayish limestone of the consistence of soft chalk. This rock when rubbed gives out a strong odour of sulphuretted hydrogen. It contains many tubular cavities, and numerous casts of Limnei, Planorbes, Cyclostomæ, Bulimi, and Cyprides, of which however it is difficult to determine the species, owing to their bad state of preservation. Bones and teeth have also been found in them belonging to

several different species and genera of Mammiferous animals; M. Cuvier has determined one of these specimens to belong to his new genus Anthracotherium. Others are apparently parts of the shell of the tortoise. The organic remains occur in the limestone strata, and the intervening softer marly beds are free from them.

These strata form the last term of the freshwater series; for a bed of clayey and ferruginous sand containing vegetable remains converted into lignite, which usually separates them from the overlying masses of basalt and basaltic breccia, cannot be supposed to belong to the strata below, since it does not preserve a parallelism to them, and has certainly been deposited after they had suffered a considerable degree of denudation.

The different strata I have enumerated are far from occurring always together, or rather no opportunity is afforded of observing them together by any section of sufficient depth towards the middle of the basin they occupy. Near its limits the upper strata are usually wanting, the lower attaining to a considerable height, where they lean against the primitive margin. From hence they incline gradually towards the centre of the cavity; so that the sand, clays and soft marls, which are remarkable at Les Tuilleries and Douc in the vicinity of the granite, dip beneath the gypseous marls of Le Puy, which are in turn covered by the limestone of Expailly and Cussac; and this order is in no instance reversed *.

On the whole, the freshwater formation of the Basin of Le Puy possesses considerable interest, from the apparent correspondence of its three principal divisions, viz. the sands and clays, the gypseous marls, and the marly limestone, with the three principal freshwater deposits of the Paris basin, to which, from the complete examination it has received, all similar formations are usually compared, and into which the surplus waters of the ancient lakes of the Haute Loire most probably discharged themselves. It is to be remarked, however, that there is no separation whatever between these different groups of the calcareous formation of Le Puy, which on the contrary graduate insensibly into one another.

The Valley of the Loire exhibits the traces of another freshwater forma-

* See the section Pl. XVIII. For a more detailed description of the freshwater formation of the Haute Loire I refer to the excellent work of M. Bertrand Roux, *Description Geognostique des Environs du Puy en Velay*, which has made its appearance since the greater part of the above was written, though I was indebted to his assistance during my stay at Le Puy for much of the information I collected on this subject.

tion before its embouchure into the great northern plain. I have had no opportunity of examining this in person; but from the Memoir of M. Passinge on the Mineralogy of the department of the Loire, published in the *Journal des Mines* in 1798, and other sources of information, it appears that the flat and marshy plain on which Montbrison stands, extending from St. Rambert to within three leagues N. of Roanne, is bounded on all sides by mountains, the Loire escaping from it only by a long and narrow channel worn through a transversal line of rocks which must once have obstructed its passage, and which there is reason to suspect is of a volcanic nature. The plain above, which those circumstances indicate to have been the bottom of a lake, is partly formed of limestone strata containing freshwater shells. They have been observed at Sury le Comtal and other spots *.

It seems probable also that the freshwater formation remarked between Jaligny and La Palisse extended northward at least to the vicinity of Roanne; and thus the idea of the former existence of a chain of lakes reaching from the highest part of the central mountain-group of France to the basin of Paris, proposed by M. Omalius d'Halloy, appears particularly applicable to the valley of the Loire, in which the limits and vestiges of some such lakes are still discoverable.

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§ 5. *Concluding Remarks.*

With regard to the analogy of the three freshwater formations above described as occurring on the elevated district of Central France, there can be no hesitation in attributing their deposition to the same æra, both from the similarity of the fossils † they contain, and of their composition. That

* I would particularly recommend the examination of this district to any geologist who may enjoy the opportunity.

† I must correct here an error from the *Bulletin des Sciences*, which has been discovered in the note to p. 18 too late to prevent the printing off of the sheet. The important remains of Mammalia mentioned as having been discovered at the Mont Perrier near Issoire, are there spoken of as if occurring in the marly limestone strata, instead of which they are found in a tufaceous conglomerate, which has been supposed by the discoverers to pass under the basaltic platform of Pardines, but which according to Professor Buckland, who has lately visited the country, leans against and envelops the base of the hill, instead of forming its substratum.

The remains of birds, anaplotheria, &c., mentioned in the same note, were however extracted from the marly strata of Volvic, and belong to an earlier formation than the former deposit, since the tufas of Pardines and Perrier were washed down from the heights of the Mont Dor after the calcareous freshwater deposits of the Limagne had suffered a great degree of degradation.

of the Cantal alone appears deficient in gypsum, but this may be owing to the very small portion of it which lies open to observation. All are remarkable for containing highly siliceous beds. The formation of the Haute Loire distinguishes itself from the others in the circumstance that the limits of the lake basins in which its strata were deposited remain obvious; so much so, that if the narrow gorges of La Voute and Chamalières were filled up, the lakes would be immediately restored nearly to what may be supposed their original level; while the deposits of the upper end of the Limagne and also of the Cantal are found at a height which overlooks an extensive and low horizon, in which no traces of a former barrier can be perceived capable of containing a body of water accumulated at that level, and we have consequently been forced to suppose these strata to have sustained a considerable degree of elevation since their deposition. The formation of the Limagne is remarkable for the alternation of strata of compact pure marl, which would seem to have concreted from a pulpy mass in the manner of the chalk strata, or the lower beds of shell marl in the Bakie Loch described by Mr. Lyell*, with the beds containing the Indusia tubulata, which bear marks of a tedious and gradual formation analogous to that of stalagmites; and by their gravelly nature, and the characters of the fossils they inclose, appear to have formed the banks† of a marsh or river, generally dry, though occasionally overflowed, rather than the bottom of a permanent lake.

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§ 6. *Tripoli Basin of Menat.*

It is as the latest freshwater formation of Auvergne, and in the fourth division of M. de Serres, that I am inclined to class the remarkable deposit from which tripoli is extracted at Menat, on the road from Riom to Montaigu.

It occupies the bottom of a nearly circular basin about a mile in diameter, surrounded entirely by high primitive rocks, and discharging its waters into the Sioule through a narrow gulley in a rock of mica-schist, which their continued erosion has evidently perforated to the depth of about 12 feet, and width of 10. Before this passage was effected, they must have formed a lake over the existing valley; the surface of which is perfectly

* Geol. Trans. vol. ii. New Series, p. 76.

† The larvæ of the genus Phryganea are well known to quit the water when the moment arrives for their change into a winged insect, and retire to the dry bank, where they leave their indusiæ.

flat, and at a lower level by some feet than the upper part of the channel mentioned above.

The sediments of this lake form the present soil of the valley to a considerable but unascertained depth; they consist of a desiccated bituminous clay of a muddy black colour and disposed in thin flakes; probably the fine detritus of the micaceous and talcose rocks which inclose the basin, coloured in part by the bitumen derived from a considerable dose of vegetable and animal matter.

Iron pyrites are extremely abundant in this clay, either globular or under the form of fishes whose moulds this mineral has borrowed. On many points the pyrites seem to have undergone a spontaneous combustion, and the clay of the strata around has in consequence been converted into tripoli, of which the parts most exposed to the heat are of a bright red, the others varying between pink, yellow, and white. These baked beds occasionally alternate eight or ten times with those that are untouched. The pyrites contained in them are flattened, and reduced to a black cinereous powder, with some traces of fusion; while those of the clayey strata are globular or reniform, and of a brilliant white metallic lustre. The tripoli is exceedingly light, and separates easily into the finest folia; so brittle moreover, that it must be taken out by hand and with great care, since a very little rough usage would pulverize it completely. It is then laid in the sun to dry, and requires no further preparation for the market.

Besides the casts of fish, those of numerous leaves occur between the laminæ of tripoli. The impressions are perfect and beautiful. What I observed, bore great resemblance to those of the willow, alder, and sycamore; besides the stalks of reeds and other monocotyledonous plants. The fish which I could see or hear of were very imperfect, but bore some resemblance to the carp and eel. It was frequently repeated to me that echini were found here; but two specimens which were shown as such in different cabinets, are without doubt merely globular pyrites. I could not discover any exuviæ of testaceous animals.

It seems probable that the formation of this simple alluvial deposit is of no very distant date. It was certainly subsequent to the revolution, if such there has been, which produced the inequalities of surface of this mountainous district.

BOOK II.

VOLCANIC FORMATIONS.

CHAPTER I.

INTRODUCTORY ACCOUNT OF THE NOTICES WHICH HAVE BEEN HITHERTO PUBLISHED CONCERNING THE VOLCANIC REMAINS OF THE INTERIOR OF FRANCE.

TO those who now travel over the mountains of central France, and see on all sides marks of volcanic agency exhibited in the most decided manner, numerous hills formed entirely of loose cinders, red, porous, and scorified as those just thrown from a furnace, and surrounded by plains of black and rugged lava, on which the lichen almost refuses to vegetate, it appears scarcely credible that, previous to the last half century, no one had thought of attributing these marks of desolation to the only power in nature capable of producing them. This apparent blindness is however very natural, and not without example. The inhabitants of Herculaneum and Pompeia built their houses with the lavas of Vesuvius, ploughed up its scoriæ and ashes, and gathered their chesnuts from its crater, without dreaming of their neighbourhood to a volcano which was to give the first notice of its existence by burying them under the products of its eruptions. The Catanians regarded as fables all relations of the former activity of Ætna, when, in 1669, half their town was overwhelmed by one of its currents of lava.

In the year 1751 two members of the Academy of Paris, Guettard and Malesherbes, on their return from Italy where they had visited Vesuvius and observed its productions, passed through Montelimart, a small town on the left bank of the Rhone, and after dining with a party of *savans* resident there, amongst whom was M. Faujas de St. Fond, walked out to explore the neighbourhood. The pavement of the streets immediately attracted their attention. It is formed of short articulations of basaltic columns planted perpendicularly in the ground, and resembles in consequence those ancient roads in the vicinity of Rome, which are paved with polygonal slabs

of lava. Upon inquiry they learnt that these stones were brought from the rock upon which the Castle of Rochemaure is built, on the opposite side of the Rhone; and were informed, moreover, that the mountains of the Vivarais abounded with similar rocks. This account determined the Academicians to visit that province, and step by step they reached the capital of Auvergne, discovering every day fresh reason to believe in the volcanized nature of the mountains they traversed. Here all doubts on the subject ceased. The currents of lava in the vicinity of Clermont, black, and rugged as those of Vesuvius, descending uninterruptedly from some conical hills of scoriæ, most of which present a regular crater, convinced them of the truth of their conjectures, and they loudly proclaimed the interesting discovery.

On their return to Paris, M. Guettard published a Memoir announcing the existence of volcanic remains in Auvergne *, but obtained very little credit. The idea appeared to most persons an extravagance; and even at Clermont a sagacious Professor who ascribed the volcanic scoriæ to the remains of iron-furnaces established in the neighbouring mountains by those authors of every thing marvellous, the Romans, gained far more partisans than the Naturalist. By degrees, however, the obstinacy of ignorance was forced to yield to conviction, and M. Desmarest some years afterwards having published his "Memoirs on the Origin of Basalt †," accompanied with maps of many of the volcanic currents of Auvergne, put an end to all doubt upon the question.

Faujas de St. Fond, whose attention had by the circumstance above mentioned been directed towards the volcanic remains in his neighbourhood, published nearly at the same time his account "*Des Volcans eteints du Vivarais et Velay* ‡;" but unfortunately, never having examined the phænomena of volcanos in activity, or learnt to distinguish with accuracy the substances which have been produced or altered by this class of natural agents, fell into numerous errors; mistook every chasm for a crater, every mass of basalt for a volcano, and saw nothing but decomposed lavas in beds of marl and sandstone. M. Desmarest's maps and descriptions were almost equally faulty. Every isolated fragment of an ancient current is with him a *culot*, or residuum of lava stopping up the mouth of a crater; and he appears to have entirely neglected all observations on the mineralo-

* "Mémoire sur quelques Montagnes de la France qui ont été des Volcans." *Mém. de l'Acad. des Sciences*, 1752.

† Mémoires de l'Acad. 1771. ‡ Fol. 1778.

gical characters and distinctions of the various lavas he discovered. The labours however of both these naturalists were of the utmost service towards the establishment of the fact,—that *numerous volcanos had broken forth in the interior of France at different and very remote periods,* and had covered most parts of the provinces of the Auvergne, Velay, and Vivarais, with the products of their eruptions.

Dolomieu likewise in the year 1797 passed hastily through Auvergne on his way to Switzerland; but in the Report which upon his return he presented to the Institute he makes but very brief mention of its rocks, and appears only to have sought in them a confirmation of his favourite doctrine, the igneous fluidity of the central globe.

Le Grand D'Aussy in his "Voyage en Auvergne," published in 1794, again called the attention of the public to the natural phænomena of this country, which were sinking into neglect; but being more qualified for romantic descriptions than scientific observation, little real knowledge on the subject is to be gained from his work: and it was only in 1802 that M. de Montlosier, after a profound and attentive study of the Monts Dor and Dome, published his Essay "*sur la Théorie des Volcans d'Auvergne,*" and exhibited in their true light the various relations and distinct characters of these interesting volcanic remains. Desmarest in his Memoir for 1771 had remarked that the perfect correspondence of repeated beds of basalt on each side of certain valleys, demonstrates their having formed parts of the same currents, the continuity of which had only been interrupted by the excavation of the valleys subsequently to the flowing of the lava. Still he was far from applying this principle to its whole extent, and continued to look upon all the isolated hills capped by basalt which are so numerous in the plains of the Auvergne, as so many volcanos denuded of their scoriæ by currents of the sea, under which he imagined them to have burst forth; and enveloped by those horizontal beds of limestone, upon which the volcanic products in reality repose. M. de Montlosier then was the first to establish the true nature of these Basaltic Peaks and Plateaux; and thus gave a key to the study of the Auvergne, without which its phænomena would present a suite of interminable difficulties and confusions. Indeed, the greater number of his remarks have been received as established facts by all later observers, whose subsequent researches have but confirmed their solidity.

M. de Buch having paid a short visit to Clermont in 1802, wrote in a letter to M. Pictet an account of some of the most striking volcanic remains

in its vicinity, which was published immediately in the *Bibliothèque Britannique*, together with a copy of a portion of Desmarest's map. It is to be regretted that this distinguished geologist threw but so cursory a glance on a country than which none can be more deserving of the profoundest attention, and the difficulties of which his experience was so well fitted to unravel and illustrate *.

In 1803 M. Lacoste, Professor of Natural History at Clermont, published some Observations on the Volcanos of Auvergne, and in 1805 some Letters on the same subject. Those who have accomplished the perusal of these works will probably have gleaned more information from them than I have been able to extract. In 1808 M. Ramond, then præfect of the department of the Puy de Dome, read to the Institute his "*Mémoires sur le Nivellement des Plaines*," to which was subjoined a list of heights measured barometrically in the neighbourhood of Clermont, and a compendious account of their geological characters. A short time afterwards, M. D'Aubuisson, who has since published one of the best general treatises on Geognosy extant, laid before the Institute his observations made during a tour through the Auvergne, Velay, and Vivarais; a tour the result of which is well known to have been his speedy conversion from a thorough belief in the Neptunian origin of Basalt and the other members of the Flœtz Trap formation, to an entire conviction of their having flowed in a state of igneous liquefaction, and their complete identity with volcanic lavas; a conclusion to which indeed no one could fail to arrive who would pursue the same straight road to the truth as M. D'Aubuisson †.

In 1815, M. le Baron Ramond presented to the Institute a second *Mémoire* on the subject, entitled "*Nivellement Barometrique des Monts Dors et des Monts Dome*," which, besides the absolute heights of more than 250 remarkable points upon these two groups of mountains, contains a detailed and methodical relation of their geological structure, drawn up with that scientific discernment and impartiality which have placed M. Ramond among the most distinguished observers of his age. To this work I have been much indebted, as well for a great body of local information as for nearly

* In 1809, De Buch also published in the 2nd volume of his *Geognostichen Beobachtungen* some letters on the Auvergne, accompanied by engravings of the Mont Dor, as an appendix to his *Voyage en Italie*, &c.; but this work I have not been able to meet with. Possibly he may have corrected and developed in it those rather crude and imperfect ideas of the phænomena of this country which are registered in the letter to M. Pictet.

† Journal de Physique. Tomes 58, 59.

all the measurements of height I have made use of in the following pages.

These, with the exception of a paper of Dr. Daubeny's in the "Edinburgh Philosophical Journal for 1820-21," and a few scattered and partial notices inserted in the *Journal des Mines*, by MM. Cocq, DeLaizer, and Cordier, are the only writings I have met with on any of the volcanic remains of the interior of France; and it is a well-founded motive of astonishment, that of the numerous men of science of whom that country is justly proud, no one should have thought it worth while to combine into one body these scattered notices; or rather, since by far the greatest part of the phænomena have never been examined or described scientifically at all, to make this part of France the subject of a general geological survey, such as has been extended to portions much less instructive, whether we consider the interest attaching itself to the facts to be observed, or the importance of the conclusions that may be deduced from them. In default of such a work, the sketch which I now present, though far from pretending to supply the deficiency, may at least serve to give a general idea of this curious and instructive territory; and perhaps excite some one with higher qualifications than myself, and more opportunities than a passing stranger can command, to examine and describe it with that attention and minuteness which the subject so well deserves.

CHAPTER II.

GENERAL ACCOUNT OF THE VOLCANIC FORMATIONS OCCURRING UPON THE ELEVATED PLATFORM OF CENTRAL FRANCE.

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§ 1.

IT has been already mentioned that the volcanic formations of central France attain an elevation much superior to that of the highest visible points of the primitive plateau. The extent of the irregular surface they cover may be better estimated from the annexed map than from any detailed admeasurements.

The disposition of these remains, combined with some striking differences in their mineralogical composition, warrants their division into two principal classes*.

§ 2. *1st Class of Volcanic Formations.*

The volcanic formations of the first class constitute the huge mountain groups of the Mont Dor, the Cantal, and the Mezen; each of which raises its colossal form from the plateau around to a much superior height, exceeding 6,000 feet from the sea in the two first, and 5,800 in the last instance.

* It must be decided by future observers whether or not I am justified in rejecting the division of these volcanic remains first proposed by Montlosier, and followed by every subsequent author, into ancient and modern; by which the colossal volcanic mountains the Mont Dor and Cantal are confounded with those insulated vents which have produced but a single eruption; and, worse than this, by which a division is made where nothing like a line of separation can be shown to exist; for the volcanic eruptions appear certainly to have continued from first to last without any very marked interval of quiet, and the excavation of the actual valleys, which these authors take as an epoch, has *in this country* at least been in continual progress, from the first elevation of its mountains out of the bosom of the sea, to the present moment. —But more of this in another place.

Although these remarkable masses differ in some respects, they resemble one another in the characters and disposition of the rocks which compose them, and bear decidedly the stamp of a common origin. Whoever contemplates attentively their peculiar features, remarking their common figure gradually sloping on all sides from some highest central points to the table-land which surrounds them, and their composition of repeated volcanic beds, bearing internal proofs of having once been fluid, and appearing to have followed the general law of all fluids in their descent, uniformly parallel to the sides of the mountain, until they reached and spread themselves to some distance over the plains below, will hardly fail to recognise in these mountains the skeletons of three enormous habitual volcanos, the Ætnas of their age.

The various agents of destruction by which they have been long, and from their insulated position violently attacked, have, it is true, almost obliterated the traces of their different craters, swept away the looser products of their eruptions, and furrowed their flanks with deep and sometimes wide valleys: but enough remains to prove their origin and testify to the prodigious energy and frequent repetition of the eruptions by which they were produced.

The volcanic rocks which enter into their composition are trachytes and basalts of various species and varieties: but perhaps a full moiety of their mass is formed of the debris of these rocks of pumice and scoriæ, with occasional fragments of granite, united into a tufa or breccia, varying continually in the size and qualities of its ingredients, its degree of induration, &c.

These volcanos, whether coeval or not, are apparently the most ancient of all those which have left their traces on this country; and though in some instances their products may have been covered by, and are thus liable to be confounded with, those of much more recent eruptions in the same neighbourhood; their general character, as habitual volcanos, is decidedly marked out by their mountainous size, the repeated alternations of their deposits, and the other peculiar features noticed above.

§ 3. *2d Class of Volcanic Formations.*

These consist chiefly of basalt and its conglomerates, although they also contain a few remarkably interesting formations of trachyte. They differ from the rocks of the first class in being scattered very generally over a large surface of the primitive plateau, instead of uniting to form distinct and lofty mountain groups.

The volcanos of the Mont Dor, Cantal, and Mezen appear to have possessed severally a single focus of action, like most of the known active volcanos; and to have created the mountains which bear these names by the continued accumulation of matter ejected from a single primary orifice.

On the contrary, the more recent eruptions which produced the second class of rocks, seem in scarcely any instance to have been repeated in the same spot, but to have burst forth singly and successively on different though neighbouring points, remarkable generally for their linear arrangement in a direction nearly N. and S.

All indeed of these explosions may be found to have occurred within the limits of an irregular zone, of no great breadth, commencing near Aubenas to the South, and prolonged towards the North through the range which divides the Loire from the Allier, as far as Paulhaguet; continued along the eastern base of the Mont Dor, and terminating in the chain of Puys which skirt the Limagne d'Auvergne to the West; thus traversing the whole of the primitive plateau from S.S.E. to N.N.W.* This peculiar disposition of the comparatively recent volcanos, in a direction coincident with that of the granitic beds, from the interior of which they have apparently burst forth, is but a repetition of a remarkable fact common, I believe, to most similar trains of vents: viz. *their parallelism to the general direction of the strata, or the axes of the mountain ranges near which they occur; and is without doubt the result of the production of some deep longitudinal fissure during the forcible elevation of such ranges*†.

These eruptions seem to have taken place at intervals, from a period subsequent to that at which the larger habitual volcanos ceased their activity, down to a comparatively recent date; since their products are found under very different circumstances, attesting an equally considerable difference of age.

Some exhibit features exactly similar to the remains of a modern eruption from Ætna or Vesuvius; viz. a conical hill with a more or less circular basin or crater at the summit, evidently the result of the accumulation round a volcanic aperture, of loose scoriæ projected from it by violent gaseous explosions.

From the lowest part of the lip of the crater, or sometimes from the foot of the cone, a current of lava is seen to have issued and flowed frequently to the distance of ten or twelve miles from its source, seeking universally

* See the Map of Central France. † See Considerations on Volcanos, p. 196.

the lowest level, penetrating valleys, occupying the beds of their streams, or spreading itself in all directions over a wide extent of plain, according to the nature of the ground it reached. Such in general is the aspect of the olcanic remains of the "Chain of Puys" near Clermont; which but for the absence of all traditional or historical accounts of their formation, might be imagined from the freshness of their appearance to be scarcely yet cold. Still there are some even of these, whose lava currents, however rugged their exterior, scarcely yet supplying sufficient soil for the support of some meagre and thinly scattered brushwood, afford, in their *position*, proofs of a considerable antiquity.

The mountain streams, which were once driven from their channels by these fiery torrents, still continued to flow, and in most cases have worn out a fresh bed from the granitic or calcareous rocks which bounded them originally. This new channel has usually been made along the line of junction of these rocks and the lava. It is in some places but a few feet in depth: in others, the violence of the stream or the long continuance of its action has excavated an entire valley below the level of the former one, the *Thalweg* of which, with its rocky load of lava, impends over it on one side, or sometimes on both. If, as is the case amongst the Cevennes, the lava has assumed during the process of cooling a prismatic configuration, long columnar ranges of basalt, forming a continued mural precipice, sometimes 200 feet high, will be seen skirting the river for a great distance. Their upper surface is flat, and often nearly half a mile in breadth; their lower may be observed to rest on pebbles rounded by the stream whose place they usurped. The cones from which these currents of basaltic lava issued, still exist, and their craters have lost little of the regularity of their form.

But it is natural to suppose that the remains of prior eruptions should have suffered still more from meteoric ravages, and the injuries to which they will have been more exposed in proportion to their superior antiquity; and thus, in fact, upon the long ridge which lies between the Loire and Allier from Prudelles nearly to La Chaise Dieu, numerous isolated hills of scoriæ may be observed, many of which have lost their conical figure, while a few only retain traces of a regular crater. The floods of lava furnished from these mouths have overflowed an extensive plain, (once the calcareous bottom of a freshwater lake,) which has since been furrowed by numerous torrents to a very considerable depth, and to a still greater by the river Loire into which these torrents flow*.

* See Plate XII.

The channels of these streams, and of the Loire itself, are but deep ravines, incased by steep walls of rock, which would be completely perpendicular but for the *debris* constantly accumulating at their base. These walls universally exhibit two or three horizontal beds of basalt and volcanic breccia, resting one upon the other, and ultimately upon the calcareous freshwater strata, wherever the ravine has penetrated below the level at which its surface is found. The friable and soft nature of the latter formation causes it to yield easily to the erosive action of the torrents, which from the great absolute elevation of this region, descend at particular seasons with considerable force; and likewise exposes it to be worn into and washed away even before the capping of basalt is removed, by the water which drains through the numerous fissures of that covering. The sapping of the subjacent marls necessarily induces the subsidence and destruction of the basalt they supported; and I was assured by some respectable inhabitants of Le Puy that the progress of these excavations is extremely sensible. Some apparently insignificant waterfalls were pointed out as receding annually many feet.

It is impossible not to perceive that the causes to which these results are owing, and which are in continual operation, even where their effects are less perceptible, tend in the course of ages to parcel out this plain into numerous separate calcareous hills; each capped by a plateau of basalt and connected with the primitive range from which the lava as well as the aqueous streams mostly descended.

The operation of the same causes will meanwhile have gradually obliterated those heaps of scoriæ that now mark out the volcanic vents, and which, from the looseness of their composition, are peculiarly liable to rapid dilapidation, and are indeed already much degraded; and this region will *then* present an aspect and constitution not resembling solely, but identical in geological character with that of the portion of Auvergne in which the freshwater formation of the Limagne abuts against the granite range which is its boundary to the West.

It is in the vicinity of this line of junction, that many calcareous hills of various heights and sizes rise from the valley-plain, crowned with a tabular capping of basalt. They are generally narrow, but of a considerable length in a direction at right angles to the boundary of the primitive range; against which they usually lean, but are sometimes separated from it by shallow transverse ravines occurring at the junction of the formations.

The bed of basalt which forms their upper surface slopes *universally*

towards the valley in the direction of their length; and where the hill is united to the granitic heights, the basalt extends over these rocks also, to some distance, generally terminating in an elevated knoll, which from its scoriaceous and torrefied aspect, and particularly from abounding in those masses which are styled volcanic bombs or tears according to their magnitude*, appears to be the site of the vent from which once flowed into the shallow valleys then existing, or spread themselves on the surface of the great valley-plain, those streams of lava which are now seen under the form of basaltic plateaux, towering above and incasing the valleys of the present day.

These streams of basalt in some instances exist in all their integrity, extending with a gradual inclination from their source on the primitive range to a considerable distance over the freshwater formation. The hill not far from Clermont called La Serre, which reaches to Le Crest, is a striking example of this nature†.

Some currents have been divided into one or more segments by ravines worn through them and the strata below, at right angles to their direction. Where these ravines have gained considerably in breadth, such segments, and the hills they crown, are severed from one another by a wide valley; yet the similar direction and slope of the plateaux is sufficient to establish at a glance their prior continuity. These transversal excavations appear to have been determined by the outcropping of the more friable strata of the freshwater formation. Some have been produced at the junction of this formation and the granite, where a series of strata of a soft bituminous sandstone intervene between this latter rock and the limestone.

In some few cases, so wide has been the destruction, that but a single or a few insulated fragments of the basaltic currents have survived; and these perhaps, attacked on every side by the agents of ravage, have been at length reduced to a *conical* form; under the protection of which they may yet outlast many of the generations of mankind; but after a time, comparatively brief in the calendar of Nature, must yield and disappear before those causes which have swept away the remainder of the current to which they once belonged.

Such are the general features, and such the distinctive characters of the

* These and similar pseudomorphous scoriæ are only produced by the aeriform explosions of a volcanic vent, and are therefore certain indications of the site of such a vent where they occur in any number. (See Considerations on Volcanos, p. 76-7.)

† See Plate II.

numerous basaltic remains which occur in the Limagne and other corresponding situations, whether as plateaux or peaks.

The various elevations at which they are found, even in the immediate proximity of the granite, some not many yards above the actual *Thalwegs* of the neighbouring valleys, while others rise from them to the height of nearly 1000 feet, and cover what appears to have been the upper surface and last deposit of the freshwater formation, seem to demonstrate a fact of no slight geological importance; viz. that the excavation of the existing valley of the Limagne and its tributary gorges was not sudden, violent, and simultaneous, the result of any great and general revolution affecting the whole surface of our planet; but was on the contrary, gradually performed by the agency of those causes which are still in operation, the unremitted sapping and mining of rocks by torrents or rivers, and their decomposition and erosion by rain, frost, and other meteoric agency.

In fact these calcareous hills still remaining at different heights, preserved by portions of basaltic currents, which once covered them in a state of fluidity, are *witnesses* of so many different epochs when the valley-plain of the Limagne existed at various elevations above its actual surface; and may be considered as the graduations of a scale for measuring the time during which its level has been progressively lowered.—But this subject must not be discussed prematurely. It will be more properly entered on when the volcanic formations shall have been described in detail, to which we proceed in the following chapter.

CHAPTER III.

DETAILED DESCRIPTION OF THE VOLCANIC FORMATIONS.

§ 1.

A MORE minute investigation of the volcanic remains of the interior of France will be best accomplished by following their geographical distribution, rather than that established from their geological characters.

They are generally visited from the North; and beginning thence, the space, through which they appear, naturally divides itself into four tolerably distinct regions, viz.

1. The Monts Dome and the Limagne.
2. The Mont Dor and its dependencies.
3. The Cantal, &c.

} Anciently united in the province of *Auvergne*.

4. The departments of the Haute Loire and Ardêche,—comprehending the two ancient provinces of the *Velay* and *Vivarais*.

§ 2. 1st *Region.—Monts Dome and the Limagne d'Auvergne.*

The Limagne d'Auvergne, as has been already noticed on the subject of its freshwater formation, is an extensive plain, or rather valley-plain, about 20 miles in breadth and 40 in length; its soil, with the exception of the calcareous and basaltic hills above described, is an alluvium consisting chiefly of boulders of primitive rocks, trachyte, and basalt, similar to those which the Allier still accumulates upon its banks.

The inclination of the surface of the valley towards this river is inconsiderable. Its low-water mark at Pont-du-Chateau is given by M. Ramond as 1027 English feet absolute elevation, and the base of the low hill upon which stands the town of Clermont at the limits of the plain, as 1204.

affording a difference of level of 177 feet; the direct distance being rather less than eight miles; and this may be taken as the average slope of the plain from its lateral limits to the river which effects its drainage. Almost immediately behind Clermont rises that portion of the primitive plateau which is intercepted between the valley of the Limagne and the channel of the river Sioule.

It constitutes an elevated platform sloping gradually to the West, but terminating on the East in a steep curtain of granitic rocks which run North and South, and are indented by short and deep gorges.

The average elevation of this table-land is 2780 feet, about 1600 above the Limagne; but in some points, where it has been preserved from erosion by a capping of basalt, it attains 3300 feet.

It lies close to the limits of the Gneiss district, but principally consists of veined granite, in which the transitions from a coarse to an extremely fine grain, are remarkably frequent and sudden. Upon this rises the "Chain of Puys" of the Monts Dome, comprehending about seventy volcanic hills of various sizes, mostly independent of each other; and forming, with the scoriæ and ashes scattered around and between them, a high and irregular ridge, directed North and South, about 18 miles in length, and averaging 2 in breadth. This addition gives to the plateau a pent-house-like form, which originally it does not appear to have possessed *.

With the exception of four or five consisting of trachyte, all these hills are volcanic cones of the most recent formation, comparatively speaking. Their usual height is from 500 to 1000 feet above their bases. They are generally clothed with a coarse and scanty herbage; some few with thick forests of beech, which were once much more abundant. This covering, however, does not hinder the examination of their composition, which is betrayed by numerous rents in the turf. Many considerable portions seem to have been always bare of vegetation.

They appear entirely and uniformly composed of loose scoriæ, blocks of lava, lapillo, and puzzolana, with occasional fragments of domite and granite. Their form is more or less that of a truncated cone; the sides rising at an angle which oscillates about 30°. The crater is often perfect, and the hill must then be mounted to observe it. Frequently, however, it is broken down on the side whence the lava issued, evidently by the weight and impetus of this substance, when propelled from the volcanic orifice in a fluid state after the formation of the cone.

* See the Map of the Monts Dome; and also Plates II, III, and IV.

In some instances eruptions have taken place on different points so near each other that their ejected matters have mingled; and in place of a single cone, an irregular hill with two or three distinguishable craters, or a long-backed uneven ridge has been the result *.

It is probable that every one of these numerous apertures has furnished its stream of lava; but the bases of the cones being sometimes partially cultivated, or covered with forests, it is impossible in every instance to discover this, nor, for the same reasons, is it easy to trace to its source every visible current, and ascertain the precise crater which produced it.

The volcano appears sometimes to have continued to eject showers of scoriæ after the lava had ceased to flow; a circumstance often remarked in the eruptions of Ætna: in this case the connection of the crater with its stream of lava will have been concealed by these loose materials. Sometimes it would seem, (and this also is common to the eruptions of the recent volcanos I have had the opportunity of witnessing,) the lava has been produced by one orifice, while the aeriform jets issued from another, the latter presenting an intact and complete cone of scoriæ and fragments, the former a breached and imperfect one.

In general, however, the currents of lava are observed to issue directly either from the crater or foot of the cone, and thence to spread over a wide expanse of the neighbouring plateau, or fill the bottom of a valley to some distance. Their surface presents a succession of shapeless and bristling masses of scoriform rock, and offers to the imagination the idea of a black and stormy sea of viscid matter suddenly congealed at the moment of its wildest agitation.

These fields of lava, which are either wholly bare or but partially clothed with stunted brush-wood, are called "Cheires" in the Patois of Auvergne †.

The lava has flowed either to the East or West according to the natural levels of the ground and the situation of the vent; and though perhaps

* For the laws which determine the figure and structure of volcanic cones, see Considerations on Volcanos, &c, pp. 69, 75.

† It is singular enough that the inhabitants of the fertile regions at the base of Ætna should call their lava rocks by a similar name, "*Sciara*." Borelli latinizes this "*Glarea*;" but the term "*Serra*," (defile, difficult pass,) seems to be the common stock whence both words are derived. The *serra* or *sierra* of the Spaniards has a corresponding signification; one of the basaltic platforms of Auvergne is still called and spelt *La Serre*.

a larger number of currents have directed themselves towards the Limagne, entering some of the steep valleys which communicate with it, the gentle slope by which the plateau descends on the west to the Sioule, has caused those which were poured out on that side to cover a wider space, and exhibit themselves in consequence more conspicuously *.

A few eruptions have taken place, on either side, out of the principal line of Puys. The most distant of these may be observed near the village of Chalucet on the further bank of the Sioule. The Puys Graveneire, Channat, and La Bannière, rise upon a second line parallel to the first and most considerable one, and immediately on the margin of the high granite plateau, where it overhangs the plain of the Limagne.

The hills of the principal chain are on many points arranged in particular groups or systems, in each of which the different cones were apparently thrown up by eruptions either contemporary or immediately succeeding one another, from ramifications of the same inferior vent. Their lavas generally resemble each other very closely; and seem occasionally to have been poured forth from neighbouring orifices into a single bath or sea, in which they are completely mingled, as if once in a state of fluidity at the same moment. From hence, as from a common reservoir, a solitary current generally takes its rise, advancing to the still lower levels.

The hills composing these groups adhere to no general arrangement. In some instances they form a straight line touching each other by their bases, or uniting even more closely; in others, an irregular group.

Although all the cones of the chain of Puys may be considered of recent formation, they are far from belonging to a single epoch. Every thing attests their having been thrown up by eruptions succeeding one another often at distant periods. The different aspects of their lava currents, some of which have yielded considerably to external decomposition, while the surface of others is still bare, harsh, and uninjured, would not perhaps *alone* prove a sufficient criterion of age, since the power of time in producing these effects on lavas varies with their varieties of mineral constitution, the more or less of iron, felspar, &c., which they contain. The considerable dilapidation of some cones, and the elevated position of their currents relatively to the surrounding soil, are less fallible signs of a superior antiquity, more parti-

* See plate III, and the Map of the Monts Dome.

cularly where they coincide, as they invariably do in this district, with the former class of marks.

Nothing, however, like an approximation to a knowledge of their positive ages can be expected; though the elucidation of this question, as we have already seen, would be a point of considerable importance.

In the middle of the line just described rises the celebrated Puy de Dome, the Giant of the Chain, as it is called by Ramond; far superior in bulk and elevation to the numerous hills which stretch from its base towards the North and South. It consists entirely of that variety of trachyte which, from a supposed peculiarity of mineral character, has been named *Domite*.

This mountain with four or five other neighbouring hills of much less size, composed of the same rock, are so closely connected in situation with some of the volcanic cones of the chain of Puys, in the centre of which they are found, as, notwithstanding their totally distinct structure and composition, to leave no doubt, in my mind at least, of their being connected likewise in origin with these cones, of their having been produced, in short, at the same time, and by a modification of the same volcanic agency.

They are scattered irregularly amongst the other Puys near the middle of the series, and are distinguishable from them at a distance by their whitish tint where the rock is exposed, and by their rounder contours.

With the exception of the Puy Chopine they consist entirely of that rock to which the most considerable of them has given the name of Domite; each appearing as one enormous mass of this substance, in which it is not easy to discover traces of any definite structure; in some parts nearly compact, solid, and moderately hard; light, earthy, friable, or completely pulverulent, in others. The substance of one mountain differs but in accidental and insignificant characters from that of another. The colour of this rock is generally a grayish or brownish white; but on many points it has acquired various tints of red and yellow from the action of acid vapours. It absorbs moisture with the greatest avidity, and this action is accompanied by a hissing noise and a considerable disengagement of air bubbles. Its texture is rudely granular; and on examination with a lens it appears to be an aggregation of imperfect microscopic crystals of glassy felspar, sprinkled with still smaller grains of augite, and occasional pallets of mica. These elements are partly separated from each other by minute pores, which render the substance rough to the touch, light, and bibulous. The larger imbedded minerals are, the glassy variety of felspar, generally cracked and mealy; mica in hexagonal or rhomboidal pallets, either bronzed or black;

hornblende in acicular hexagonal foliated crystals generally of a deep black, and highly lustrous along the planes of cleavage; and sphene; as well as specular and titaniferous iron in dispersed grains, blade-shaped laminæ, or regular octohedrons.

That these different substances crystallized at the same period, is proved by the intimate manner in which their crystals are interwoven. Yet in general it appears that those of mica and hornblende were entirely formed before the complete crystallization of the felspar; for perfect crystals of both these minerals may be frequently seen enveloped or as if suspended in the centre of a large crystal of glassy felspar. Very commonly the included crystals appear to have been broken, bent, or split, probably by the movement which the surrounding substance suffered when propelled upon the surface of the earth from the volcanic focus; the cracks produced in the mica or hornblende are invariably penetrated by felspar.

This rock is extremely liable to decomposition, which affects it often to the depth of some feet. Its parts are then disaggregated, it assumes an earthy aspect, and crumbles between the fingers; the crystals of felspar become carious, lose their lustre; and finally the whole mass is resolved into a meagre and ashy powder, in which the crystals of hornblende, mica, and octohedral iron are found uninjured.

The volcanic nature of Domite has never been contested; and indeed it is sufficiently evidenced by the pumice stones which accompany and are inclosed by it; the vitreous nature of its crystals of felspar; by its being porous, impregnated with muriatic acid, coated with sulphur, with sublimations of iron, &c., not to mention its identity with the trachyte of the Mont Dor, which has still stronger proofs of a volcanic origin.

Surrounded, and partly embraced by cones of scoriæ and lapilli, and remote from the rocks of the Mont Dor which alone they resemble in substance, these hills have offered a most perplexing problem to all the cursory visitors of Auvergne, and at the same time an ample field for conjecture to theorists. Hence the contradictory opinions that have been started on their origin. Desmarest considered the rock which composes them, as a granite calcined *in situ* by a volcanic conflagration environing it;—Saussure, a petrosilex which had undergone the same extraordinary operation;—Dolomieu, Mossier, Montlosier, and De Buch, a granite triturated or liquefied by volcanic agency below the earth, and then by a sudden expansion of gas propelled through different apertures over which it was consolidated in the form of huge bubbles.

Ramond raised as an objection, and a very strong one it is, to these hypotheses, in their full extent, that the phænomena supposed to have taken place here are gratuitous inventions, not even suspected of having occurred anywhere else; that the volcanic energy, as far as we are acquainted with it, acts in a totally different manner; and that to imagine a mountain of the magnitude of the Puy de Dome baked throughout upon the spot, is an absurdity which can only be equalled by the supposition of its having been swelled up like a bubble without bursting.

He denies, moreover, that each of the Domitic hills is independent of the rest, the insulated production of a single and local operation, and asserts that this rock shows itself partially on many other points in the vicinity,—a fact tending to prove that these separate masses of the same substance were once, if they are not still, united, and constituted together a large bed, covering an extensive surface of the plateau, which succeeding volcanic eruptions and other mechanical injuries have in great part destroyed, concealed, and reduced to the seemingly insulated remnants which now alone show themselves.

M. Ramond concludes that this bed is a ramification from the trachytic currents of the Mont Dor. M. Daubuisson also has professed the same opinion; so that the authorities on either side seem nearly balanced.

It is, I believe, now generally recognised that Domite is but a variety of trachyte; the same rock, in all essentials, which constitutes the greater part of the Mont Dor and Cantal, the Euganean Hills, the Monti Cimini, and the Isles of Lipari and Ponza *. It is therefore wholly unnecessary, nor should we be warranted in the attempt, to account for its production by any other mode of formation than that which appears common to similar rocks in other places; unless such an explanation should be in this instance opposed by any manifest improbability.

There is every reason to conclude the trachytes of the Mont Dor and Cantal, as well as the phonolite of the Mezen, to have been propelled from a volcanic orifice in a state of liquefaction,—in short as lavas, and to have followed the inclination of the ground they occupied, flowing in a manner differing only from that of basaltic lavas in proportion to their different consistence and very inferior fluidity, and the accidental circumstances which may have concurred to modify their disposition.

It is evident that under similar circumstances of the surrounding levels

* Vid. Brocchi, Cat. Rag. *passim*.—Brieslak, Institutions Geologiques. Vol. iii. &c. &c.

and of propulsive force, the tendency of a mass of lava to quit the neighbourhood of the orifice from which it is emitted, will be in exact proportion to its fluidity; and when the fluidity is at its *minimum*, it will accumulate immediately around the orifice: one layer of the half-congealed and inert substance spreading over that which preceded it, till the whole assumes the form of a dome or bell-shaped hillock perforated in the centre by the chimney or vent, through which fresh matter may continue to be expelled, but which will at the end remain closed by that last sent up. Now the variety of trachyte which composes the Puy de Dome and the neighbouring Domitic Puys consisting almost wholly of felspar, and therefore possessing the lowest possible specific gravity, and at the same time a very rude and coarse grain and highly porous structure, is precisely that species of lava which we should expect *à priori* to have possessed the *minimum* of fluidity when protruded into the air *; and we therefore understand perfectly why instead of flowing in thin and continuous sheets or streams to a distance from its vent, like the basaltic lavas produced about the same time and from the same fissure, it has accumulated in dome and bell-shaped hillocks on the point where it was emitted. That this *was* the mode of production of these masses of trachyte, that they were thrown up on the spots they now occupy, is proved by their rising in every instance either from the middle or the side of a regular crater and cone of scoriæ †.

If it could be imagined possible for the volcano of the Mont Dor to have sent forth a vast current of trachyte in this direction of which these hills have been supposed the remaining segments, in spite of the fact that the great elevation of the granite ridge upon which they rest above the surrounding country, renders it the last of all directions which such a current could have taken, and in spite of the improbability that a rocky bed of which the Puy de Dome, a mass rising 1600 feet above its base, is *merely a detached remnant*, should have left no traces of its existence in the interval between that mountain and the Mont Dor, a distance of 7 or 8 miles: yet a still stronger objection to this hypothesis remains behind, viz. the improbability that the position of *each* of these remains should severally coincide exactly with that of the vent of a separate recent eruption; that the *only* points on which the remnants of this supposed bed are to be found, should be *precisely those* on which, from the disturbance occasioned

* See Considerations on Volcanos, p. 92—96.

† See Plate IV, and the map of the Monts Dome.

by the volcanic explosions, there would be good reason to suppose it might have been destroyed and carried off.

The theory of Von Buch evidently approaches more nearly to this explanation than that of Daubuisson and Ramond. Von Buch supposes the Domite to have been "granite liquefied by volcanic heat:" I also conceive it to have been, like all lavas, a mass of granite, or some congenerous crystalline rock, which, while confined beneath the surface of the globe at an intense temperature, was suddenly allowed to expand, by the bursting of the overlying rock, and was consequently liquefied, or so far softened by the immediate generation of highly elastic fluids, both gases and aqueous vapour, through every part of its texture, as to be protruded, by the tumefaction incident to this process, through the clefts of the overlying crust.

The part of Von Buch's theory with which I agree the least, is his supposing these hills to be hollow, and blown up like a bladder. I imagine, on the contrary, the aëriform and highly elastic fluids, the expansion of which elevated the lava, to have remained chiefly where they were generated, viz. in a state of uniform and intimate dissemination throughout the texture and between the solid crystalline particles of the porous and elastic mass; and not by any means to have united into one great bubble or volume beneath an overlying cake of the lava, as is implied in Von Buch's theory,—a theory which Humboldt has adopted and applied, I think with rashness, to all trachytic formations. I need not dwell any longer on this topic, as the laws by which I conceive the trachytic, as well as every other variety of lava, to have been determined in its rise and appearance on the surface of the earth, have been developed in detail in another work, (Considerations on Volcanos, pp. 85—129); and that the peculiarities which distinguish these particular trachytic formations will be best noticed when they are individually described amongst the chain of Puys of which they form links.

To this we proceed immediately; and I propose to commence their description with the Puy de Dome which rises in the middle of the chain, and take the remaining hills in the order of their succession from this towards the N. and S., pointing out at the same time the currents of basalt, or the domes of trachyte which appear to have been produced from the several vents marked by the cones of ejected matters. The accompanying map* is referred to in the numerals prefixed to the names of these hills. It was

* See Map of the Monts Dome.

drawn up entirely from my own observations, and I believe its accuracy may be relied on.

§ 3. *Description of the Chain of Puys.*

(62.(*Puy de Dome.* (Absolute height 4842 feet.)—This mountain, which occupies the centre of the Chain of Puys, and in all its proportions leaves the others far behind, rises to the height of 1600 feet from the average level of the plateau around.

Its figure is that of an irregular cone very obtusely truncated, the upper surface sloping considerably to the West. A rounded eminence on its eastern summit gives it, when viewed from that side, somewhat of the figure of a cupola. Its appellation, however, (in Latin Dumum or Podium Dumense) has no reference to this resemblance, but is derived from the woods with which it was formerly clothed, and the remains of which still cover the foot of its eastern slope. In consequence of the very different consistence of its substance, which resists decomposition and atmospheric erosion much more in some parts than in others, two sides are, as well as the summit, entirely covered with thick grass, and present a smooth and gently curved outline, while that of the others is broken by rocky projections, giving them an aspect of a ruder character.

The fissures of the harder portions of rock are lined both with laminar and octohedral crystals of iron; those of the more friable and earthy with similar sublimations, but which in these points assume the brightest tints of blue and green, and occasionally with a coating of sulphur. The substance of the rock itself is in many places frequently stained throughout with varying shades of an ochry yellow, a citron, a rose, a scarlet, and a grayish blue colour. Fragments of domite thus tinged, when rubbed together, give out a strong smell of muriatic acid, and M. Vauquelin has detected in them the presence of this acid by analysis. The exhalations to which these effects must be attributed were probably evolved through crevices from the interior of the mass of trachyte during the process of cooling, and were the result of the partial decomposition of its inner substance by intense heat; as the elastic vapour it contained escaped through the pores of its outward surface, and thus diminished the pressure which had before opposed the decomposing influence of the caloric*.

* See Considerations on Volcanos, p. 125-6.

Spallanzani in describing the specular iron of Stromboli remarks, with some probability, that its occurrence amongst lavas is much rarer than it should be if produced solely by the action of internal heat on the iron of this substance, which is always present; and supposes, with probability, that the volatilization of the metal and its subsequent crystallization is owing to its combination with muriate of ammonia, which is known to produce this result by experiment.

A chapel was anciently erected on the summit of the Puy de Dome, of materials brought from a distance; (the additional labour and expense incurring of course a redundancy of gratitude from Our Lady, to whom it was dedicated); and the ruins of this building have probably strewed the sides of the mountain with the blocks of basalt which are occasionally found there. The scoriæ occurring in the same situation have been evidently projected there by the explosions of the neighbouring cones. Exceedingly light and porous fragments of domite resembling pumice in these characters and in their rudeness to the touch, but without its vitreous filaments, also form part of the loose debris of this mountain; but they clearly belong to its mass, and many of them may be observed imbedded in the more solid rock.

It is difficult to discover any thing in the *structure* of the Puy de Dome to indicate the particular mode of its production. The general reasons given above with reference to this as well as the other trachytic hills of the chain, are however sufficiently conclusive. On the south side, the base of this mountain has been perforated by volcanic explosions, which in all probability immediately succeeded the protrusion of the trachytic lava, and which have left a large crater, half-incircled by abrupt cliffs of trachyte, and containing within it a complete cone composed of fragmentary trachyte, scoriæ, and lapillo. This cone goes by the name of the Puy de Besace (39), and the ridge of the surrounding crater of the Puy de Gromanaux (38). On the north side of the Puy de Dome and immediately contiguous to it, is another crater belonging to the Petit Puy de Dome, to the description of which we proceed.

Chain of Puys North of the Puy de Dome.

1. *Petit Puy de Dome.*—A volcanic cone, one of the largest though not the most perfect of the chain, leans against the northern flank of the Puy de Dome. Viewed from a distance, it appears to be a dependence of this

latter mountain, and hence the name it has received of Le Petit Puy de Dome. Upon a closer inspection the different nature of the materials of the two mountains is immediately apparent; the Petit Dome being composed entirely of fragmentary matter, basaltic scoriæ, sand, and ashes. This volcanic cone reaches an elevation of 4186 feet, and is lower by 656 feet than its colossal neighbour.

It contains a very regular crater, shaped like the interior of a deep bowl, and called by the mountain herdsmen "Le Nid de la Poule," "The Hen's Nest." Its diameter and depth are nearly equal; the latter measures 292 feet from the highest point of the circumference, of which the southern portion is much the lowest. To the North and East an outer semi-circular ridge running parallel to the inner one, appears to be the fragment of an older cone defaced when that now existing was thrown up.

From the western base of this hill, a stream of basaltic lava called the *Cheire de l'Aumone* takes its rise, and extends to a considerable distance over the slope of the granitic platform, but is at length lost under a cultivated soil, or confounded with other and seemingly later currents, which have taken a similar direction. This lava was most probably emitted at the epoch of the eruption of the Petit Dome.

2. *The Great Suchet,*—a saddle-shaped eminence with some slight traces of a crater on its southern slope, is connected with that last described by means of the *Little Suchet* (63), one of the Domitic hills, which stands at the vertex of a right angle formed by the ridges of the hills it unites. The fragmentary matters that compose the Great Suchet were apparently projected by the eruption which produced that mass of trachytic lava; and this idea, suggested by their proximity in position, is confirmed by the numerous blocks of trachyte and pieces of pumice which enter into its composition.

3. *Puy de Come.*—Rather to the west of the meridian on which stand most of the Puys, rises that of Come, remarkable for the regularity of its conical form, for its height, exceeding 900 feet from the plain around, whence it rises majestically at an angle of about 40°; and above all, for the prodigious dimensions of the lava current it has poured forth. This current is also one of the most interesting of the whole chain, from the obstacles it has met with in its course, and the changes it has effected in the surface of the ground it overflowed. The sides of this hill are covered with forest-wood; its summit presents two distinct and very regular craters; one of them with a vertical depth of 250 feet, is of considerable diameter.

The cone was apparently thrown up after the eruption of its stream of

lava; which instead of issuing from either crater, takes its rise at the western base of the hill.

At a very short distance from its source, the lava has encountered an angular protuberance of granite, which caused the current to separate into two branches. That to the right, the most considerable of the two, spread itself over a vast surface, and aided by the gradual inclination of the granite platform, pursued its course to the west till it found an obstacle in a long line of hill, consisting of alluvial tufa from the Mont Dor, covered by an ancient plateau of basalt. Thus impeded in its progress, the lava followed the sweep of the hill in a N.E. direction; and finding an issue at length between this and a granitic knoll which obstructed its progress towards the north, poured down on the present site of the castle and town of Pont Gibaud; immediately above which it seems to have met and flowed over a more ancient stream from the Puy de Louchadière*.

Thence both together poured in a broad sheet of lava down the steep side of a granitic hill which formed the eastern border of the valley of the Sioule, dashing forward against the rocks on the opposite side, and usurping the channel of the river, down which they pursued their course to the distance of more than a mile.

The Sioule, thus dispossessed of its bed, has been constrained to work out a fresh one between the lava and the granite of its western bank, which in consequence is extremely precipitous. But, before this was accomplished, there is every appearance of its waters having been so far obstructed as to form a lake, covering the flat and alluvial surface now forming the meadows of Pont Gibaud.

In one part of this new channel, where the valley has a slight bend, and the torrent of lava, being opposed by a salient rock accumulated to a considerable thickness, the excavation effected by the river has disclosed its internal division into vertical jointed columns, the lower portions of which are straight, and well formed, the upper twisted into various curves, and less regularly polygonal. The wall of lava is about 50 feet high, and the columnar division is prolonged incompletely to the extent of between 200 and 300 yards.

The rest of the lava filling the valley where it is about the third of a mile in breadth, is split by fissures, mostly vertical, into amorphous masses which still, in various points, evince a tendency to the prismatic form. This is

* See Plate III.

perhaps the most marked instance of all Auvergne in which the lava of one of the very recent volcanos assumes a decided columnar division. In the Vivarais, as will be seen in a future chapter, this circumstance is of frequent occurrence.

The sketch (Plate III.) was taken from a basaltic plateau on the summit of the granitic range of hills, west of the Sioule, from whence the greater number of Puys may be observed; that of Côme being the most conspicuous as well as the nearest. The whole course of this branch of its lava, as well as that of the Puy de Louchadière, is seen from this point.

But the Sioule was not to suffer from this invasion alone. The other branch of the lava current of Come, which flowed on from the point of separation in a direction W.N.W., soon reached the bed of this river, about three miles above the spot of the other irruption, and pouring over its banks filled up the entire valley with an immense causeway, more than 100 feet high. Exhausted by this effort, it proceeded but a short way down the bed of the stream towards the N., and stopped where the village of Mazayes now stands.

The baffled waters of the Sioule here, as at Pont-Gibaud, obstructed by the rocky dyke thus suddenly thrown across their channel, must have given birth to a lake by their stagnation, and would probably have ended, as in the other instance, by wearing away a passage parallel to their former one, had not the hill forming their western bank, not in this instance composed of granite, but of a soft alluvial tufa, yielded, at some distance up the stream, to the excessive pressure of the dammed up waters. An immense excavation, still subsisting, was broken across this hill, through which the lake emptied itself into the bed of the Monges at no great distance, and through which the Sioule still joins this latter stream about three miles above their former confluence.

A considerable body of back-water still remained behind in that part of the valley of the Sioule intercepted between the dyke of lava and the emissory thus forcibly created; which, from the inclination of the ground to the N., could not vent itself by this opening; and here a stagnant piece of water called the Etang de Fung, and used by the Seigneurs of Pont-Gibaud as a stock-pond, existed till within a few years, when its drainage was artificially effected. The high banks which rise on each side of the long marshy meadow now occupying the site of the old pond, still present the correspondence of angles so generally observable along channels of running water.

On the opposite side of the enormous causeway of lava to which this diversion is owing, another small piece of water, occupying the bed of a

tributary rivulet choked up in the same manner, is dignified by the name of the Lake of Mazayes, and its insignificant drain now runs into the Sioule through the remainder of the wide and deep valley which this river itself once excavated and possessed.

The changes thus effected do not only present themselves to the eye of a nice observer, but are exhibited in a manner not to be mistaken by the most casual; and in fact they result so simply and necessarily from the causes brought into action, that I should not have dwelt so long upon their details, but that they serve to exemplify the mode of formation of other lakes in the Auvergne and Velay, and the origin of other changes in the surface of a country or direction of its rivers, where every link in the chain of causes and effects is not quite so palpable.

The whole superficies of the plateau covered by the lava of Come cannot be estimated under ten square miles. Its thickness is not to be ascertained, since no excavation has been made through it; where the current has met with any obstacle, it must of necessity be considerable, and thirty feet may be taken as the probable average.

It is one of the most ragged Cheires of the Monts Dome, presenting a succession of continual asperities, following one another like the waves of an ocean, with similar depressions between. Upon walking over its surface,—no easy task,—it appears to consist of chaotic heaps of rocky and angular blocks of compact basalt, tossed together in every variety of disorder; yet, in the deep and narrow intervals between these heaps occur little patches of fresh and flowery turf, and knots of underwood spring from their clefts, contrasting strangely with the horrid desolation which prevails over this extensive wilderness.

Near the limit of the northern current, at some distance from Pont-Gibaud, is a natural grot in the basalt; from its interior gushes a small spring, which is partly frozen during the greatest heats of summer; and is said to be warm in winter; probably, however, only seeming warm by contrast with the external temperature.

The water is apparently frozen by means of the powerful evaporation produced by a current of very dry air issuing from some long fissures or arched galleries which communicate with the cave, and owing its dryness to the absorbent qualities of the lava through which it passes. This is a phænomenon common to caverns in other volcanic districts.

The basalt of the Cheires de Come and de l'Aumône is almost identical in its mineralogical characters; it is replete with irregular cellular cavities,

is of a dark grayish blue colour, and contains a notable quantity of felspar. It is sufficiently tough to be worked for building-stone, and cuts well under the chisel. Nodules of pure white quartz are not unfrequently found enveloped by it, appearing to have suffered from heat only on its surface, which is cracked, and sometimes shows a commencement of fusion.

4. 5. *Puys de Barmet and Filhou.*—Two small cones, the last of which has a semi-crater well marked out; that of the former is nearly effaced. These two hillocks were probably thrown up from side apertures, at the epoch of the eruption of the Puy de Come.

6. *Puy de Pariou.*—From its aspect, and that of its lava, this Puy may be supposed the product of one of the last eruptions which convulsed the country. It is also one of the most considerable and regular cones of the chain.

A segment of a former crater half incircles it on the North, and here the whole process of this and similar formations is manifest. The aëriform fluids developed in the interior of an ebullient body of subterranean lava having at length forced a cleft in the overlying rocks which impeded its expansion, struggle upwards through this aperture, carrying with them at every eructation showers of scoriæ and their comminuted fragments. These accumulate round the margin of the orifice into a hill, necessarily approaching more or less in figure to the solid which would be generated by the revolution of an obtuse scalene triangle round one of the angles of its base; and this hill is called a volcanic cone, which, it must not be forgotten, when most perfect, is but a truncation of the geometrical one *.

But when the intumescent lava itself has risen and poured itself forth from the vent, it must by its weight and impetus generally break down and carry away part of the loosely built hill incircling the aperture whence it issues, and a semi-cone only then remains of which the crater appears open on one side. If on the contrary the eruption is not sufficiently violent to raise the lava above the lips of the aperture, a complete cone is the result, with an equally perfect crater.

After the lava has ceased to be emitted, the gaseous explosions recommence and continue for a certain time, by which a second cone is formed, which in the absence of subsequent disturbing causes remains perfect, as in the example of the Puy de Pariou now under consideration, where since the flowing of its vast current of lava the volcanic mouth evidently threw

* See Considerations on olcanos, p. 67. et seq.

up prodigious showers of scoriæ and puzzolana, creating the beautiful cone and crater of Pariou upon the brink of that which had been formed by the first explosions of the eruption.

This newest crater has the figure of an inverted cone. It is clothed to the bottom with grass, and it is a somewhat singular spectacle to see a herd of cattle quietly grazing above the orifice whence such furious explosions once broke forth. Their tracks round the shelving sides of the basin in steps rising one above the other, like the seats of an amphitheatre, make the excessive regularity of its circular basin more remarkable to the eye.

Its depth is 300 feet, and circumference 3000. The inclination of the sides of the cone and of the crater are both about 35°. The acute ridge resulting from their junction is so little blunted by time, that in some parts it scarcely affords space to stand on. Its highest point is 738 feet above the southern base of the Puy.

The lava of Pariou is as instructive with regard to the circumstances which accompany the movement of this substance in viscid torrents over a large tract of country, as its cone on those by which such mountainous excrescences are suddenly thrown up.

Its first direction is to the North-east, and the current appears to have set with fury against a long-backed granitic eminence opposing it on that side. Thence, led by a considerable slope towards the South-east, it coasted the base of this hill; and leaving to the right another protuberance of the primitive plateau on which now stand the church and hamlet of Orcines, advanced to a spot called La Baragne. Here it met with a small knoll of granite capped with scoriæ and volcanic bombs, marking the source of a much more ancient basaltic bed known by the name of Prudelles. Impeded in its progress, the lava accumulated on this point into a long and elevated ridge, which still bears the appearance of a huge wave about to break over the seemingly insignificant obstacle. But an easier issue offered itself in two lateral valleys having their origin in the part of the plateau occupied by the lava current; which, separating consequently into two limbs, rushed down the declivities presented on either side.

The right-hand branch first deluged and completely filled an area surrounded by granitic eminences, and probably the basin of a small lake; thence entered the valley of Villar, a steep and sinuous gorge, which it threaded exactly in the manner of a watery torrent, turning all the projecting rocks, dashing in cascades through the narrowest parts, and widening

its current where the space permitted, till on reaching the embouchure of the valley in the great plain of the Limagne, it stopped at a spot called Fontmore; where its termination constitutes a rock about 50 feet high, now quarried for building-stone. From the base of this rock gushes a plentiful spring, the waters of which still find their way from Villar beneath the lava which usurped their ancient channel *.

The branch which separated to the left plunged down a steep bank into the valley of Gresinier, replacing the rivulet that flowed there with a black and shagged current of lava; entered the limits of the Limagne at the village of Durtol; and continuing the course marked out by the streamlet, turned to the North, occupied the bottom of the valley lying between the calcareous mountain Les Côtes and the curtain of granitic rocks, and finally stopped on the site of the village of Nohanent. Here, as at Fontmore, an abundance of the purest water springs from below the extremity of the lava current. The various rills which drain the valley of Durtol and its embranchments, have recovered their pristine channel, and filtering through the scoriform masses which always form the lowest surface of a bed of lava, flow on unseen, till the rock above terminates, and they issue in a full and brilliant spring. Above this point, consequently, is seen the anomaly of a valley without any visible stream; and the inhabitants of Durtol are condemned in seasons of drought to the strange necessity of seeking at Nohanent, a distance of two miles, the water which flows there beneath their own houses. A similar phænomenon is very general throughout the Auvergne, wherever a current of recent lava has occupied the bed of a mountain rivulet, not sufficiently copious or violent to undermine the lava above, or open a new side channel through its formed banks.

In its appearance the Cheire of Pariou is even more bristling and rugged than those already described. M. D'Aubuisson justly compares it to a river suddenly frozen over by the stoppage and union of immense fragments of drift ice.

In the work to which I am obliged so often to refer on the general laws and conduct of the volcanic forces †, it has been made to appear that this asperity of surface in a lava current is owing and generally proportioned to the high specific gravity of the lava, which determines the ascending force

* These and the other lava current of the chain of Puys are all to be traced on the Map of the Monts Dome.

† Considerations on Volcanos. London: Phillips, 1825. pp. 119—20.

of the bubbles of vapour that expanding in its interior, rise, and escape from its surface as it flows onward. The lava of Pariou, which is composed almost wholly of augite, and therefore of high specific gravity, confirms this law. The same circumstance accounts for the other characteristics of this rock, which is perfectly compact in the interior of the current, while the outer portions are cellular and cavernous. The cavities, often of large dimensions, are lined with a dark vitreous varnish, and from their sides project numerous stalactitic protuberances, and slender filaments, coated in the same manner.

The colour of this basalt is a deep shade of bluish gray; it contains imbedded crystals of augite, and a few of glassy felspar, and bears a great resemblance on the whole to the current from the Monti Rossi, which in 1669 destroyed a part of Catania, and reached the sea.

It was in all probability the eruption of the Puy de Pariou, which threw up those large accumulations of puzzolana observable on both sides of the granitic ridge of Ternant and Clersat.

7. *Puy de Fraisse.*—Between the Puys of Pariou and Come lies that of Fraisse, a saddle-shaped hill of very little interest.

Its basalt, which is seen only in erratic blocks, differs from that of the Puys already described by containing crystals of olivine.

64. *Clierson.*—This Puy occupies the centre of an area formed by the four volcanic cones, Pariou, Le Grand Suchet, Côme, and La Fraisse. Its figure is most precisely that of a bell, as the plates will show *. Turf and brushwood cover the swelling curve of its steep sides, and a ring of broken rocks forms the edge of the circular and flattish capping which crowns it. This capping appears to be remains of an outer envelope, the lower parts of which have been worn away. The whole substance of the hill is a light and porous trachyte, differing in nothing from some parts of the Puy de Dome. The upper half of the hill is perforated in all directions by caves and galleries formerly pierced for the extraction of this stone, which is supposed to have been held in esteem by the Roman colonists as a material for sarcophagi, in consequence of its properties of absorption. These caves abound in fragments of pumice detached from their walls, in the substance of which much of this mineral is observed to be enveloped. Pumice we know stands in the same relation to trachytic rocks as scoriæ to basalt, and these pumiciform parts are created of course in the former rock

* See Plate IV.

by the same accidents which occasion the extremely cellular and scoriform parts often found in the substance of the latter.

M. Ramond supposes Cliersou and Le Petit Suchet to have been united formerly; and indeed this follows of course from his theory as to the origin of all these domitic hills from the Mont Dor. I am fully of opinion that it was protruded from the vent on the spot where it now stands, and that it owes its form, as explained above, to the very low fluidity of its substance at the time of its emission. If any of the surrounding cones of scoriæ was thrown up by the same eruption, it must most probably be the Puy de la Fraisse.

8, 9. (65.) *Puys de Sarcouï* and *Des Goules.*—Immediately to the north of Pariou rises a linear group consisting of three hills, and having the same direction with the general chain, viz. N. and S. The central one, Le Grand Sarcouï, consists entirely of domite; the two others, Le Puy des Goules and Le Petit Sarcouï, are ordinary volcanic cones.

The first of these has a shallow but wide crater at its summit. It is remarkable only for the fragments, of gneiss apparently much altered by volcanic heat, of a black trachyte passing into a resinous state and enveloping pieces of gneiss, and of a variety of basalt with variolitic spots, which occur mingled with scoriæ, puzzolana and ashes, in its composition. This has been exposed by the cutting of the high road from Clermont to Limoges, which occupies a narrow pass between the Puy des Goules and that of Pariou at an absolute elevation of 3310 feet, and during the winter is subject to dangerous *tourmentes*, or snow storms.

The Little Sarcouï has a semi-crater, exactly fronting and embracing part of the circumference of its larger namesake. It gives rise to a current of lava on its eastern side, which follows the sweep of a granitic ridge as far as the village of Egaules, where it is confounded with that of the Puy de Jume. In mineralogical characters it differs little from that of Pariou.

65. *Le Grand Sarcouï.*—Between the two last described hills, and in close contact with each at its base, rises the Puy de Sarcouï, one of the most remarkable and perfect of the trachytic domes of this district. In figure it is completely a flattened and rather elongated hemisphere, and is aptly compared by the mountain shepherds to a kettle placed bottom upwards. Of this singular shape, which attracts the attention from a great distance, the plates that accompany this volume will convey a very accurate idea. The trachyte which composes this hill is rather looser in texture and lighter in colour than that of the Puy de Dome, it has also

fewer imbedded crystals, but is essentially the same rock. Like the Puy de Dome, Sarcouï has parts of its substance impregnated with muriatic acid, and stained with mixed and brilliant hues of red and yellow. Like Cliersou it has been quarried for sarcophagi, many of which still remain in an unfinished state in its caves, and the name of the hill is supposed to be derived from the purpose to which its stone was applied. In these caves may be perceived indications of the structure of the hill in massive beds or strata, which, as far as can be made out from the thick vegetation and quantity of debris which cover the surface, follow the curving slope of its sides, and envelope its nucleus concentrically, in the manner of the coats of an onion.

The summit is nearly circular and quite flattened, covered thickly with heather, and strewed with scoriæ launched probably from some of the neighbouring Puys. Near the foot of the hill on the east a number of small rocky knolls of trachyte pierce through the cultivated soil, and appear to connect themselves with the base of this larger mass of the same substance.

The very intimate union of Sarcouï with the Puy des Goules, together with the fact that the latter cone does not appear connected with any current of basalt, and moreover consists in great part of fragmentary trachyte, leads to the opinion that these two hills are of contemporaneous production, the latter being formed of the fragmentary substances projected by the aëriform explosions which accompanied the emission of the trachytic lava of Sarcouï.

This group of volcanic hills deserves to be thoroughly studied by those who wish to obtain an insight into the mode of formation of the dome-shaped masses of trachyte to be met with in many other volcanic districts, and which sometimes attain to the magnitude of the colossal Chimborazo. A rock of trachyte is rarely to be observed on so small a scale, so completely insulated from every non-volcanic rock in position, so accessible to examination, or presenting so perfectly the figure which has been supposed characteristic of this formation. Those who will imagine the effect which would be produced by heating a very thick hasty-pudding in a closely covered vessel which it completely filled, until its intumescence force it to exude through a crack or hole in the cover of the vessel, over which the matter, quickly congealing by exposure to the air, would form a bulky excrescence, will understand exactly the mode of formation which I attribute to the trachytic dome of Sarcouï, the Puy de Dome, and the other similar hills.

I beg pardon for this homely illustration, but it explains my meaning better than any elaborate description.

10. *Le Creux Morel.*—To the north of the Puy de Fraisse, and west of the group last described, is a large extent of level plain, covered with turf; the soil is a medley of volcanic fragments ejected by the surrounding cones.

A singular depression is observed in it near the Puy des Goules, evidently the result of a volcanic explosion, but differing from other craters in having a conical mount of scoriæ raised on one side only, while the margin of its remaining circumference is even with the plain around. It is 115 feet deep; has no lava current; and was probably but a subsidiary spiracle of one of the neighbouring volcanic vents. A violent wind, or a slanting line of projection, may have caused the matters thrown up to fall upon the side rather than around the orifice.

Its scoriæ contain crystals of black and green augite, and of olivine; the erratic blocks of basalt are unusually dense and hard.

11. *Puy de Chaumont.*—This is a very regular and rather large cone, with a crater at the summit nearly effaced by the accumulation of debris. Its lava and scoriæ resemble those of the Creux Morel, with which it was probably contemporaneous. No perceivable current; but the basaltic rocks which here and there pierce through the soil of the plain on the east, are rather referable to this than any other Puy.

12. *The Puy de Lantegy*—is scarcely more than a hillock of scoriæ, covered by numerous fragments of domite, with a small crater broken down towards the west. Its lava, like that of the other Puys in the vicinity, is soon lost under the thick bed of volcanic ashes sprinkled over the plain, and the occasional cultivation which this circumstance induces.

13. *Puy de la Goutte.*—This segment of an immense crater is connected in situation and doubtless in origin with the extraordinary medley of rocks called Puy Chopine, which it half encircles.

Fresh-looking scoriæ, and blocks of a compact basalt with olivine, augite, and fragments of domite, show themselves on its sides and interior, wherever the turf is rent away; and the elevation of the soil to the west seems to indicate a current to have taken that direction.

66. *The Puy Chopine* *.—This is a very remarkable volcanic production,

* See Plate VII.

and has proved and still will prove a most perplexing subject of study to every geologist who visits Auvergne. Daubuisson left it after three visits, and candidly avows that he had not acquired any light on its probable mode of formation, nor any clear idea of its structure and composition. It may therefore appear presumption even to attempt to describe it; but, though to obtain a clear knowledge of the composition of a hill which is evidently a confused medley of heterogeneous substances, is at the outset impossible, yet its general aspect and principal features may be without difficulty remarked and sketched.

The figure of the Puy is irregularly conical, and its sides on some points are so steep that vegetation is prevented from covering them by the fragments which are continually detaching themselves and rolling to the bottom; and hence two wide rents on the east and south lay bare its upper half; the lower is hid by the immense and daily increasing accumulations of debris.

Its composition, as far as it can be observed by help of these barren faces, which from their excessive steepness and the crumbling nature of their materials are very difficult of access, is a mixed assemblage of various primitive and volcanic rocks in different stages of alteration from volcanic heat, acid vapours, and atmospheric injury.

This singular combination, however, exists but on that portion of the Puy which fronts the S.W., S., S. E., and E. The remainder is a massive and nearly vertical bed of domite alone. The whole mountain rises out of the semi-crater of the Puy de la Goutte, which closely embraces it from N.W. to East, passing by the South.

I spent some hours in examining the Puy Chopine at three different visits; and it appeared to me that, notwithstanding the confusion which reigns through some of its parts, the disposition of the principal masses is sufficiently obvious, and may give a clue to the ænigma of its formation.

The lowest rock which shows itself on the face of each rent above the talus of debris that conceals the base of the mountain, is a conglomerate of scoriæ and volcanic ashes, through which protrude massive blocks of basalt, evidently *in situ*. This basalt is either cellular and scoriaceous, or affects a spheroidal structure, contains olivine and augite, and puts on the dull aspect of the older rocks of this genus.

Upon this rests a tabular bed of granite. The line of contact is straight and inclined to the horizon at an angle of about 15°, traversing the whole face of the mountain, from S. W. to S. E.

The granite for the space of 3 or 4 feet from this line is stained of a red

colour, and so entirely disaggregated that the foot sinks into it; it becomes sounder as it is more distant from thence, but its masses present every where an irregular and dislocated appearance. Higher up it passes on various points: 1. into a small-grained granite; 2. a sienitic rock similar to that of the Lac d'Aidat; 3. a fine-grained trap (hornblende slate) separating into rhomboidal pieces.

Then transitions are effected suddenly, and only remarkable here for occurring within such narrow limits, as the same passages on a larger scale present themselves on other points of the gneiss district. These assembled primitive rocks are backed to the north, and in part supported to the west by a rocky mass of domite which constitutes all that side of the mountain.

At the summit, and wherever this junction takes place, which is far from being as regular and decided as that with the basalt below, the granitic rocks are more or less altered. The granite is blanched, and has lost its consistence; the trap is also discoloured, cracked, and its fissures coated either by a reddish-brown ferruginous varnish, or dendrites of specular iron, evincing that it has been traversed and affected by volcanic exhalations. Small patches of boles and breccias which are seen on a few of these points, seem merely to result from the mechanical confusion, decomposition, and chemical changes wrought in the united rocks already mentioned during their protrusion.

It appears then that the Puy Chopine, taken in general, consists of a mass of primitive rocks, showing signs of great disturbance, included between a bed of domite on one side and basalt on the other, and this aggregate rises immediately out of the crater of a volcano.

These general features leave no room to doubt that the whole mass was raised into its present position by the eruption which threw up the scoriæ that form the Puy de la Goutte. Among the clefts which are broken across the superficial crust of rocks, by the expansive force of subterranean lava, and through which all volcanic eruptions take place, it must sometimes happen that two fissures meet or branch off at an angle, and occasion the minimum of resistance upon that point. An eruption consequently taking place there, may readily be supposed to elevate a portion of the rocks forming this angle in a solid state, and set it on-edge upon one side of the vent. This mass would then form an obstacle to the fragments and the scoriæ thrown from the vent on that side, and force them to accumulate into a semicircular ridge on the opposite side of the orifice of eruption, which is

precisely what seems to have occurred in the Puy de la Goutte. The basalt which underlies the granite dates, no doubt, from this eruption, and is the outcropping of the subterranean mass whence the aëriform explosions proceeded. With respect to the trachyte, which also in part underlies the granite and backs it to the N. and W., it is difficult to determine whether it owes its formation to the same eruption, or existed previously in contact with the granite, and was raised into its present position at the same time with it. I am inclined, however, to prefer the first opinion, and to think that we have in this close union of granite and hornblende rock, trachyte and basalt, in a mass of rocks protruded from the crater of a volcano, a lucid and unhoped-for example of the *contemporaneous* elaboration, almost before our eyes, and at a recent epoch, of the two genera of volcanic rocks, trachyte and basalt, the first from granite, the second from hornblende rock, by the friction, disintegration, and intense heat which attends the developement of volcanic action. If we suppose, which is most probable, that the inferior and intensely heated strata of the original rock contained the same varieties of mineral composition as its superficial parts still exhibit, we can perceive how the same process of expansion, acting on the more feldspathose portions, would convert them into trachyte, which changed the more ferruginous or hornblendic parts into basalt; the quartz in each being dissolved and partly carried off by the aqueous vapour. These different lavas would intumesce and might rise at the same time through the fissures on either side of the angular and still solid portion which was heaved up by the violence of their escaping efforts; and thus this portion of granite and hornblende rock would remain, as it does, wedged in between outcropping beds of trachyte on one side, and basalt on the other. This solution of the ænigma offered by the phænomena of the Puy Chopine, corresponds accurately with the appearances of the mountain, and in my opinion is in complete harmony with the laws of volcanic action.

14—19. North of the Puys de Chaumont and Chopine is a group of seven or eight volcanic cones scarcely separated from one another, and in all appearance the product of contemporaneous eruptions from different points of the same fissure.

The two which rise in the centre of this group, united by a narrow ridge, far exceed the others in height and magnitude. Each has a large crater at its summit; that of the most northerly, the Puy de Jume, is 210 feet in depth, and beautifully perfect.

This system of volcanic mouths has sent forth a vast torrent of lava.

towards the east; which, entering a branch of the valley of Arniat, by this opening descended to the calcareous plain below, on which it forms an extensive plateau, already elevated many yards above the soil around; and presenting a perfect type of the formation of some more elevated and older basaltic plateaux in the vicinity, whose connexion with the granite heights whence they probably flowed, has been destroyed, and which, therefore, but for this object of comparison might have appeared more problematical.

The rivulets which drain the hills of Arniat and Laqui, still unite in their former channel, and flow on unseen beneath the bed of lava, till at its extremity, the whole river gushes forth, in the most abundant and fertilizing springs of the country. This basalt incloses numerous crystals of augite and olivine, with a few of felspar and some plates of mica.

20.—*Puy de la Nugère.*—A polystomatous volcanic cone. Its principal crater is an oblong basin, large and deep; pouring forth a body of lava towards the North-west.

Numerous smaller apertures seem to have been in action at the same time, and after raising in common the north-eastern projection of the mountain, to have furnished another mighty torrent of lava, which is seen to fall in a broad cascade down its steep sides, and incircling a prominent knoll of granite that checked and divided the current, to join the former stream*. Together they inundate a considerable valley, and escaping from it through a narrow pass, descend to the site of the town of Volvic, where they are either stopped, or lost beneath a later current from the neighbouring Puy de la Bannière.

The rock of Nugère has for three or four centuries past been quarried, and in use as the principal building-stone of the country, under the name of "Pierre de Volvic." It is throughout penetrated by numerous irregular cells lengthened in the direction of the current; it contains a large proportion of felspar, so much so as to make it approach in character to trachyte. This also gives it a light gray colour, and the property of cutting with facility. The fissures occasioned in the mass by its retreat, are few and distant. Hence blocks of great dimensions can be extracted. I have seen some worked into slabs of 20 feet by 6. These fissures are lined with a profusion of specular iron, which is also thickly disseminated through the pores of the rock.

21. *Puy de Louchadière.*—This is without doubt the most striking of

* See Plate V.

the chain. Completely isolated from the others, it rises as a majestic cone to the height of more than 1000 feet from the western plain, at an angle of 35°, and to the absolute elevation of 3956 feet.

An enormous crater, broken down towards the west, and measuring 486 feet in vertical depth from the highest point of the ridge, is scooped out of this mass. At its bottom a capping of basalt conceals the orifice of the volcano, almost appearing still to boil up from it as a spring gushes from its source, and hence issues a vast current, which first falling abruptly down a steep declivity into the plain, encumbers a wide extent of it with hilly waves of black and scorified rocks, and then pursuing the direction of its slope, proceeds to join the Cheire of Côme immediately above Pont-Gibaud. The figure of this mountain originated its appellation, "La" or rather "Lou Chadière" is in Auvergnat "*the arm-chair.*" It is covered with forests, which add considerably to the beauty, and take from the horror of its aspect.

22—25.—From the base of Louchadière, a group of 5 or 6 smaller volcanic hills, closely connected, extends upon a line towards the north. They present the vestiges of as many craters, which send forth currents of lava to the east, west, and south. The thick forests which clothe these Puys render it difficult to examine them minutely. Their lavas are uniformly basaltic.

26. *Puy de Pauniat.*—This cone stands by itself to the N.E. of the latter group. It has a semi-crater facing the N.W., and seems to have furnished its contingent to the sea of lava which deluges the plain in that direction, but which later showers of volcanic ashes, a coating of rank grass, and here and there the plough, have combined to smooth over and conceal.

27. *Puy de Thiolet.*—An imposing hill of an oblong figure partly covered with wood. Its principal crater is elliptical and of vast dimensions. This cone has emitted streams of lava from three of its sides. That which issues from below the eastern base was anciently quarried, and the cathedral of Clermont was built from it; it was afterwards discovered that a similar stone was to be found nearer that town, viz. at Volvic, and these quarries were abandoned.

28. *Puy de Beauny.*—At some distance to the N. E. of Thiolet is a circular plain about a quarter of a mile in diameter, once the bottom of a piece of water called the Lake of Beauny, which a few years back was drained. On the south it is overlooked and partly embraced by a volcanic cone, which exhibits a crater breached towards the lake-basin. On the north and east it is inclosed by a semi-circular ridge of loose scoriæ and granitic frag-

ments, about 150 feet in height, on the outside of which is seen the granite.

This wide crater appears to have been opened through the primitive strata by some more than ordinarily violent explosions; and the mouth was afterwards in all probability closed by the lava of the Puy de Beauny, which, first filling the basin, issues from it towards the west, and unites itself to the western streams of the Puy de Thiolet.

The lavas of the last described 7 or 8 Puys hemmed in by ranges of granite on the north and west, and by their own ejections on the east, seem to have flooded the whole space thus inclosed with their united currents. They resemble one another very closely in composition; and this similitude extends to those of La Nugère and Louchadière. They are of a light colour, abound in felspar, are more or less cellular, highly sonorous, and contain few or no imbedded crystals. It is probable, indeed, that these Puys all date from the same epoch, and were produced by the same crisis of subterranean expansion.

The chain of Puys in appearance ends here; and though more than one eruption has taken place North of this point, no connecting links are visible; a wide interval of granite must be traversed before their sites are reached, and they might be supposed entirely independent of the phænomena of the Monts Dome, were it not that they are found to have occurred upon the same meridian to which the other eruptions have shown so decided a preference, and bear marks of having been produced about the same period. They may therefore be considered as the extreme ramifications of the same primary fissure of eruption.

29.—The first is the *Puy de Chalar:* it rises at a short distance E. of the small town of Manzat; and three miles and a half in a direct line from the Puy de Beauny. It is a large and sufficiently regular volcanic cone, with a vast crater broken down to the N.W. From its interior a copious current of very black, compact, and scorified basalt takes its rise, and descends by a gentle acclivity into the valley of the Morge.

30.—Rather within a mile to the N.E. of the Puy de Chalar is a circular lake, called *Le Gour de Tazana,* about half a mile in diameter, and from 30 to 40 feet deep. Its margin for a fourth of the circumference is flat, and elevated above the valley into which the lake discharges itself. Every where else it is environed by steep granitic rocks, thickly sprinkled with small scoriæ and puzzolana, and rising about 200 feet from the level of

the water. These fragments are all that indicate the volcanic origin of this gulf-like basin, but these are sufficiently decisive. No stream of lava or even fragments of any large size are perceivable.

This curious and, in Auvergne, rare variety of crater is identical in characters with some of the largest and most remarkable of the volcanic *maare* in the Eiffel (particularly that of Meerfeld); with this only difference, that the former has been drilled by the volcanic explosions through granite, the latter through a superficies at least, of grauwacke slate and secondary sandstones.

The peculiar characters by which it distinguishes itself from the other volcanic vents we have been describing, viz. its great width, the total absence of all lava-current, and the extremely small quantity of ejected scoriæ by which it is surrounded, are in my opinion to be accounted for, as in the case of the maare of the Rhine district, by supposing a series of rapid and violent discharges of vapour through the vent, from a mass of lava at a great depth, which owing to this depth and the freedom with which it was enabled to discharge the elastic fluids that occasioned its intumescence, subsided without having risen sufficiently high within the vent to allow of many scoriæ being projected beyond its orifice.*

The incircling rocks show marks of considerable disturbance. They consist of two varieties of granite: one fine grained, and of the usual elements; the other coarse, with very large crystals of felspar, and having the mica chiefly replaced by pinite, both crystallized in hexahedral prisms, and amorphous.

The Gour de Tazana is not quite a solitary instance of this phase of volcanic development in Auvergne. The Lac de Beauny, already described, seems to owe its origin to similar explosions on a minor scale; and we shall have occasion hereafter to remark its repetition in more than one locality of the Mont Dor.

Eastern Line of Puys.

The three following volcanic cones have been already noticed as occurring near the eastern limit of the granitic plateau; and at some distance from the meridian which forms the axis of the chain, and from which the greater number of Puys deviate little.

* See a paper on the Rhine-volcanos, in the Edinburgh Journal of Science: June 1826.

31. *Puy de la Bannière.*—An eruption has, in this instance, taken place on the summit of a granitic eminence overlooking the valley-plain of the Limagne, and a vast current of lava has taken that direction, rushing tumultuously down the side of the mountain, and spreading over a large level surface below.

No regular cone or crater is to be observed; but prodigious heaps of scoriæ, lava-blocks, and fragments of granite, surround the spot whence the current issued. The shelving sides of the hill might be expected to prevent the accumulation of these incoherent substances in the figure they usually affect. The town of Volvic is built upon the basalt of La Bannière, which crosses and apparently covers that of La Nugère. Copious springs gush from below it both at St. Genest and Marsat. It is of a black colour, compact; contains numerous crystals of augite, and fewer of olivine and felspar; and in all its characters bears the strongest similitude to the basalt of some of the most ancient plateaux.

32. *Puy de Channat.*—This cone is partly covered with wood, which perhaps conceals the vestiges of its crater, no where else observable. Its scoriæ frequently envelop fragments of granite, and large knots of olivine and hornblende. The latter are rounded and amorphous, appearing as if they had suffered bouldering, or external fusion. They are of a deep black, and exhibit a laminar structure only on fracture, the faces of the laminæ are highly lustrous. The same crystals, with grains of compact felspar of a bluish white colour, are to be found in the lava, of which this Puy has furnished two currents. One descends directly to the east, and is lost immediately under a cultivated soil; the other directs itself at first to the S.W. but is conducted by the inclination of the ground into the bed of a small stream, which it continues to occupy, making the circuit of a granitic hill covered by a fragment of a more ancient basaltic current, and disappearing towards the east below the village of l'Etang.

33. *Gravenère.*—This volcanic cone has been more frequently visited and described than any other, from its immediate vicinity to Clermont. The eruption to which it owes its origin burst through a bed of basalt, which covered the eastern slope of a long crescent-shaped granitic eminence, called the Puy de Charade, one of the most elevated protuberances of the plateau.

The scoriæ, lapilli, and puzzolana, of which the cone of Gravenère consists, have an exceedingly fresh appearance; they are red, reddish brown, and black, and are often met with in the form of bombs, tear-drops, and long ropy sticks. The puzzolana is in great request as an ingredient in the

mortar of all the neighbouring edifices; it is called "gravier noir" by the natives, and hence the mountain's name.

No crater is visible; probably it was destroyed during the emission of the last current of lava, which seems to have descended nearly from the apex of the present cone towards the north into the valley of Royat, stretching thence into the plain, as far as Mont-joly and Les Roches.

Two other streams are seen to proceed from the midst of scoriæ half-way up the sides of Gravenère, on the east and south. The former is diverted from its course by a calcareous eminence, on which rises the Puy de Montaudoux, a conical rock of older basalt, and both unite to deluge an extensive surface of the plain below.

The interior of the bed of basalt in the valley of Royat is disclosed on each side of the vast excavation already effected through it by the rivulet. It measures 65 feet in thickness, and is divided by vertical fissures into imperfect columns. From some of these fissures spring the copious sources which by means of an aqueduct supply Clermont with an abundance of the clearest water.

Within the gardens of Mont-joly, at the extremity of the northern current, is a small cavern rivaling the celebrated Grotta del Cane in its phænomena. A constant emanation of carbonic acid gas takes place from its sides and bottom; its mephitic qualities have been ascertained by repeated experiments.

Above the village of Aubières I found some large fragments of the freshwater limestone enveloped by the lava. They were extremely brittle, tinged with a reddish hue, and presented a crystalline or saccharine texture. They effervesced readily with acids.

The basalt of Gravenère taken from the inner parts of the current is compact, dense, of a deep slate colour, or grayish black; and contains crystals of augite, with a few of olivine and glassy felspar. The superficial parts are more or less cellular and scorified. Its texture is sometimes highly crystalline.

From its proximity to the populous town of Clermont, the surface of the Cheire of Gravenère has been forced into cultivation by the most assiduous industry. The process is to break up all the projecting masses of basalt, by blasting; and from their fragments and scoriæ, aided by dressings, a soil has been created and clothed with vineyards, which almost rivals the well-known fertility of the sides of Ætna and Vesuvius, where the same method has been constantly pursued.

Puys facing the Puy de Dome.

34. *Puy de Colière.*—About 200 yards from the eastern base of the Puy de Dome, rises a diminutive cone of this name, which, seemingly from its insignificance, has as yet escaped the notice of every writer on the Monts Dome. It has, however, to all appearance sent forth a considerable stream of lava, which, after spreading to some extent over the plateau, encountered a hill of granite above Font de l'Arbre ; a division took place, and one portion joined to the left the current of Pariou at Les Cheix ; while the other threaded the narrow valley of Fontanat, and accompanied its rivulet to Royat, where it either terminated or has been since covered by the stream descending from Gravenère.

M. Ramond apparently overlooked this current as well as the small Puy it proceeds from, when he described Font de l'Arbre as "situated on an isolated remnant of *ancient* lava."

The basalt of the current of the Puy de Colière is dark coloured, dense, brittle, and remarkable for being generally replete with numerous nearly spherical cells. Its crystalline texture is evident to the naked eye, and exhibits a multiplicity of diminutive crystals of glassy felspar ; those of augite are not so conspicuous ; but some few apparent crystals of this mineral and of olivine are scattered through the mass.

35.—A short distance south of this is a still smaller cone, known to the shepherds by the name of Chuquet* Geneto, probably from the broom (*genèt*) which grows upon it. It has produced no lava, and was perhaps thrown up by some casual explosions finding a vent in this direction, during the more violent eruption of some one of the neighbouring Puys. Its scoriæ, which are very fresh, contain many imbedded fragments of granite at different stages of alteration by heat, and nodules of hornblende similar to those of the Puy de Channat.

36, 37. *Puys du Petit et Grand Sault.*—Two small cones west of the Puy de Dome, in which it is difficult to discover traces either of craters or lava, from the quantity of turf which clothes and surrounds them.

Chain of Puys, South of the Puy de Dome.

38. *Puy de Gromanaux.*—An eruption has in this instance, as was noticed before, forced its way through a bed of domite ; the prolongation

* The term "Chuquet" acts as the diminutive of Puy, and is applied by the Auvergnats to any small knoll, or cluster of rocks.

of the base of the Puy de Dome. A vast semicrater facing the N. W. discloses this rock *in situ*, and it projects also on other points of the Puy.

From the midst of this crater rises—

39. *The Puy de Besace.*—A double cone covered with turf; and, like the last and other neighbouring Puys, presenting numerous fragments of domite mingled with its scoriæ and lapilli. It perhaps contributed to the basaltic lava currents which have deluged the western slope of the granitic plateau.

40. *Puy de Salomon.*—A wide crescent, half incircling a crater which has pushed forth a large stream of lava to the west. Erratic fragments occur on this Puy of a compact basalt, of a light gray colour, and a granitoidal texture so comparatively coarse as not to call for M. Cordier's mechanical analysis, but exhibit its imperfect crystals to the naked eye. Three fourths of these are of glassy felspar, the remainder of green augite, with a few of bright yellow olivine. It is remarkable that the cellular cavities of this lava are lined with more perfect crystals of the same substances, which were perhaps deposited from a state of sublimation as the rock cooled.

41. *Puy de Montchié.*—Three volcanic mouths combined to raise this mountain. Its northern crater is of vast diameter, and 340 feet in depth. That to the S. W. appears to have given rise to the current of lava which descends below Alagnat.

The great proportion of domitic fragments which enter into the composition of this and the neighbouring hills, and which are scattered over the plain on each side, lead to the presumption that a considerable bed of this rock once existed on their line, and has been subsequently broken through, and launched into the air by their explosions.

42. *Puy de Barme.*—This volcanic hill stands by itself, to the west of the chain. It has three distinct craters; two at its summit which are perfect, and a third broken down towards the S. W. From hence issued an immense stream of lava, which widely flooded the western slope of the plateau, and reached the Sioule on the site of Pont des Eaux. Usurping the channel of this river, it flowed on towards the north, and stopped beyond the village of Olby.

M. de Montlosier, who so well describes the changes wrought in the direction of the Sioule by the lava of Côme, seems not to have observed this third invasion, which has forced its waters to wear themselves a new bed through the hill forming their western bank, and consisting of a clayey alluvial tufa, a ramification of the Mont Dor.

43. *Puy de Laschamp.*—This hill when viewed from a distance has

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nothing of a volcanic appearance. It is a long-backed ridge formed by the united ejections of three or four craters, which have considerably defaced one another. Its highest summit, seemingly the result of the last eruption, is nearly 1000 feet above the village of Laschamp in the plain immediately below.

On the north exists the greater part of a large oblong crater; and a current of lava springing from its base, turns to the east, and covers a considerable space inclosed between the Puy and the opposite heights of granite. Overflowing here, one portion of the current takes to the left, skirts the base of the Puy de Dome, and descends to Enval; the other enters the little valley of Beaune, but disappears before it arrives at Font-fredde, beneath the meadows of the low ground it occupies. The basalt of this current is cellular, of a light gray colour, very similar to that of the Puy de Salomon above described, has a large dose of felspar in the composition of its base, and imbedded crystals of this mineral and of olivine. A separation into rude columns is observable on some points. Another semi-crater to the left has also emitted a stream of lava, which after joining those of the Puys Lamoreno and Montchar, two dependencies of Laschamp closely united to it, spreads over a part of the western slope.

To the south of the Puy de Laschamp rises an irregularly circular system of volcanic cones, the produce of many repeated eruptions within a small space, which in all probability succeeded one another very closely, or raged at the same epoch. This is the most interesting portion of the whole range to every observer, whether geologist or not. The extraordinary character of the view from any one of these Puys impresses it forever on the memory. Perhaps there is no spot amongst the Phlegræan fields of Italy or Sicily which displays in greater perfection the peculiar features of a country desolated by volcanic phænomena.

It is true that the cones thrown up around are partially wooded and in general covered with herbage; but the sides of some are still naked, and the interior of their broken craters, rugged, black and scorified, as well as the rocky floods of lava with which they have loaded the plain, have a freshness of aspect, such as the products of fire alone could have preserved so long, and offer a striking picture of the operations of this element in all its most terrible energy.

The first cone which presents itself commencing on the east is,

44. *The Puy de Mercœur.*—It has a small crater on the summit, and is not otherwise remarkable.

45. *The Puy Noir* or *de la Meye*,—which occurs next, has a large semi-crater 590 feet deep facing the east; from its interior proceeds one of the most bulky lava currents of the Monts Dome. After covering a wide space above Fontfredde with a sea of hills, it enters the valley of Theix, and occupies the winding bed of its rivulet as far as Julliat, where it terminates a course of 10 miles, performed with a fall of 1700 feet.

The scoriæ and basalt of the Puy Noir are exceedingly dark coloured, and justify its appellation. The latter contain frequent crystals of augite and olivine; and where the current has been obstructed by rocks of granite narrowing the gorge through which it flowed, an imperfect columnar configuration may be observed.

46. *Puy de Las Solas* or *de la Gravouse*.—This cone incloses a widely breached crater. Its steep walls of black and crumbling scoriæ half surround an abyss, which almost seems still to vomit forth an impetuous torrent of lava. This stream immediately joins that of the

47. *Puy de la Vache*,—a ruined crater, the exact counterpart of the last Puy, to which it is united by the base.

The whole appearance of these two remarkable hills forcibly demonstrate that the showers of scoriæ which created them, were thrown up previously to the emission of any lava; and that this substance afterwards rising in a state of liquefaction through the chimney of the cone, filled the funnel-shaped cavity of the crater, broke down by its weight the weakest side, and rushed forth to deluge the surrounding soil. In the interior of the upper part of the remaining circumference of the Puy de la Vache, the point to which the lava rose in the crater is still marked by a projecting ridge of light scoriaceous matter of a reddish yellow colour, rich in specular iron, and considerably decomposed by sulphureous vapours; apparently part of the frothy scum which formed upon the surface of the ebullient lava, and adhered to the side of the vase at the moment of its being emptied.

A cap of basalt still chokes up the orifice below, and connects itself with a vast current, which being swelled by the addition of those of Las Solas and the Puy de Vichatel immediately opposite, takes its course towards the S. E., and by damming up the channel of two rivulets near their confluence, has given birth to the two lakes of La Caissière and d'Aidat, the latter of which is a large and picturesque expanse of water *.

From this point the stream of lava entered a narrow granitic gorge, and

* Sidonius Apollinaris is said to have had his habitation on its banks.

swelling out again as the valley widens towards St. Saturnin, filled its basin completely, and stopped where Le Grand Tallende is now situated. The distance traversed by the lava is about 12 miles, and the difference of level between its source and termination 2230 feet.

Near the spot where the town of St. Saturnin stands, a small body of stagnant water appears to have existed at the period of this irruption; for beneath the bed of basalt, there about 40 feet deep, a stratum of clay shows itself, containing an abundance of vegetable remains reduced to charcoal by the intense heat of the superincumbent lava.

It is remarkable that the clay immediately in contact with the basalt is hardened, and divided to the depth of 10 or 12 inches into small vertical prisms, exactly imitating in miniature the columnar groups of basaltic plateaux *. The Cheire of La Vache, &c. is particularly ragged and bristling, as indeed are those of all the Puys of the southern extremity of the chain, —a character they owe to the prevalence of augite in their composition; while the lavas of the northern Puys, as we have seen, are almost wholly composed of felspar, and consequently present much fewer asperities †.

Some of the scoriæ of the Puy de la Vache appear to have suffered an alteration from the action of acid or sulphureous vapours; they are found of various tints of white, yellow, blue, red, and black; they abound in specular iron, which is also found to have insinuated itself by sublimation into the fissures of compacter lava-blocks, forming within them the most delicate dendritic ramifications.

48. *Puy de Vichatel.*—This cone has a regular crater sloping towards the N. E. Its lava mingles with the currents of La Vache and Las Solas.

49. *Montchal.*—A regular cone with a semi-crater fronting the N.; it is partly wooded. Its lava probably is concealed by that of

50. *Montgy.*—This Puy has sent forth a considerable stream of lava from a crater broken down towards the S. E., exactly in the direction of Montchal; which appears to have divided the stream into two branches. They are lost immediately under the ashes and other loose matters with

* It is clear that the retreat which in the one is effected by the loss of caloric, is in the other caused by its increase. The principle of fluidity in either case disappears, and a contraction must take place.

I observed the same sort of natural equivoque in frequent instances in the Velay; where the odd conjunction of these different substances in which the same effect is produced by directly opposite causes, was rendered more striking by the equally regular columnar structure of the clay, and the basalt which had hardened it.

† Scrope on Volcanos, pp. 119, 120.

which the plain around has been strewed by subsequent explosions, and the vegetable soil to which their decomposition has given rise.

51. *Pourcharet.*—A large and imposing cone, the most westerly of the group. Its sides are steep; and on the summit is a wide but shallow crater. Lava has issued from its north-western base, and followed the slope of the plateau to some distance in that direction.

52. *Montillet.*—A crescent-shaped ridge of little elevation; from the semi-crater it incloses proceeds a current of lava, which turning to the right joins that of Pourcharet.

53. *Montjughat.*—This Puy stands by itself, and is one of the most regular of the chain. The crater is deep and large. Its lava appears to have joined that of Montillet.

54. *Puy de la Taupe,*—so named from the resemblance which it bears, in common with many of the rest, to the labours of some giant mole. It has a crater breached towards the west, and its lava covers a considerable surface on that side. The basalt of this current is remarkable for containing even more crystals of augite than that of the neighbouring Puys. It is exceedingly dark coloured and compact.

55, 56. *Puys de Broussou* and *de Combegrasse.*—These cones, closely united, have craters open to the south-east, and furnish a current which turns to the east, and reaches that of La Taupe.

57, 58. *Puys de la Rodde* and *de Chalard.*—The former is a large hill apparently produced by more than one volcanic mouth. It has a semi-crater facing the south, and gives birth to a current of lava which spreads to the right and left, reaching the village of Aidat, at one extremity of its lake.

The scoriæ of the Puy de la Rodde are remarkably rich in crystals of augite of the most beautiful regularity, and the basalt of its current equally abounds in apparent crystals of this mineral and of olivine.

The Puy de Chalard appears to have been thrown up by a lateral aperture, immediately after the eruption which created the Puy de la Rodde.

59. *Puy de Charmont.*—This cone has a large and deep crater broken down towards the south-east; from the bottom issued a current of dark coloured lava, but was prevented by a ridge of granite from reaching the lake of Aidat.

60. *Puy de l'Infau* or *l'Enfer.*—A low but large crescent, the remaining walls of a vast crater, whose site is now occupied by a circular bog called La Narse d'Espinasse, from the nearest village.

The plain to the east and south is formed of ancient beds of basalt, and

a violently explosive eruption has evidently made its way through the continuation of these : their sections may be observed round the interior of the crater. A current of lava has been vomited by this opening towards the east.

61. *Puy de Montenard.*—The most southerly of the Chain of Puys belonging to the Monts Dome, and in an isolated position. Its figure is irregular, the result of two neighbouring craters. One of them is open to the S. E., and a copious stream of lava has issued from it covering a wide space on the S. and E., and reaching to the bed of the river Monne. But the cultivation of the plain from which this Puy rises, and the quantity of more ancient lavas which have flowed from the Mont Dor in its direction, renders it difficult to ascertain the boundaries of the recent currents with due precision.

§ 4. *Volcanic Rocks the Produce of earlier Eruptions.*

The eruptions that produced the chain of Puys just described, though far from being contemporaneous, evidently belong to a period during which the volcanic energy raged with peculiar fury along the line they occupy ; a fury, by which it appears to have been completely exhausted, and which may be the cause of its subsequent inertness.

But a close observation convincingly demonstrates that previous to this æra of intense activity, eruptions were continually taking place upon the same line, without any quiescent interval of sufficient duration to enable us to mark out a decided line of separation between the most recent and the more ancient volcanic remains of the class that now occupies our attention.

For the sake of perspicuity, however, it has been thought necessary to imagine such a division ; and the rocks already described are therefore united under the general denomination of *recent*, and those to which we now proceed, under that of *ancient* volcanic formations.

The former have been mentioned in the order of their geographical occurrence ; the nature and position of the latter will be most clearly exposed by considering them in the inverse of what appears to be the chronological order of their formation, commencing with the products of the eruptions which seem to have immediately preceded those already described in the Chain of Puys.

They consist of currents of basalt, of which the cones either no longer exist, or are partly obliterated : which are more or less denuded of their

accompanying scoriæ or scorified surfaces: affected by decomposition: often divided and parcelled out into isolated plateaux or peaks: and finally which overlook valleys or ravines of considerable depth evidently excavated since their formation.

67. The Volcano of *Chalucet* on the left bank of the Sioule below Pont-Gibaud, is one of the first connecting links between the recent and more ancient eruptions, possessing the principal characteristics of either class. It has burst forth from mica-schist which environs it on all sides; and a considerable cone composed throughout of lapilli, puzzolana, and scoriæ of every fantastic form, still marks the site of its orifice. At the northern base of this hill facing the Sioule, commences an enormous current of basalt, which evidently once flowed into and entirely choked the valley, extending more than two miles down the stream.

The river has subsequently worn itself a new channel between this accumulation of basalt and its northern bank; and the vast dimensions of this excavation eaten out of solid strata of mica-schist to the depth, in parts, of 200 feet below the level of its former bed, upon which the basalt is seen to rest, evinces the immeasurably long continuance of the erosive action, as well as its irresistible power*.

The massive cliffs of basalt that beetle over the gorge thus formed, have a striking aspect. The thickness of the bed averages perhaps 150 feet; its upper surface is level, but covered with scorified protuberances, and, where it has not been forcibly brought into culture, as ragged as any Cheire of the Monts Dome.

These portions of cellular and shaggy basalt are, however, merely superficial; the interior and great mass of the current is compact, and remarkably divided into very small prisms grouped together in curved and radiated bundles. These in some instances, at the foot of the bed, vault over a void space, the basalt having apparently moulded itself on some knoll of loose fragments, or rounded rock of mica-slate, now destroyed; and these shallow grottoes are the horrible volcanic mouths vomiting lava, and representing the "nigri spiracula ditis" of which M. Le Grand has favoured us with so poetical a description †.

On some points the prismatic is replaced by a spheroidal concretionary

* "I attribute the excavation to the *river* which still flows there, because the undisturbed and perfect state of the cone of loose scoriæ demonstrates that no denuding wave, deluge, or *extraordinary* body of water has passed over this spot since the eruption."

† *See* Voyage en Auvergne par Le Grand d'Aussy, vol. iii. p.374.

structure on a small scale, the basalt separating at a touch into minute angular globules, rarely exceeding the size of a pea, the "pièces séparées grenues" of the French geologists.

There is not the least probability of this structure having been produced or even disclosed here by decomposition; on the contrary, large horizontal masses of this nature alternate with others, that are prismatic on a proportionately small scale; the latter modification of structure appearing to pass into the former by the sole diminution of the axes of condensation *. Where the basalt is seen in immediate contact with the supporting mica-schist, this last rock has suffered a partial disintegration, and is stained of a bright red colour to the depth of a few inches.

In its mineralogical characters the basalt of Chalucet resembles some of the most ancient varieties; it is compact, heavy, of a dull aspect, a dark colour, and without any apparent imbedded crystals. It frequently envelops fragments of granite and mica-slate, considerably altered; and I have found amongst its scoriæ blocks of a porphyry similar to that of Chateix, rendering it probable that the remarkable bed observed in that locality, and considered to be connected with the volcanic eruption of Graveneire, extends also into the vicinity of the volcano of Chalucet.

68. *Puy de Charade.*—A considerable granitic eminence on the western edge of the plateau. Its summit is covered by a massive bed of basalt, prolonging itself with a rapid slope towards the east, till it is interrupted and concealed by the more recent volcanic cone of Graveneire, whose eruption appears to have exploded from beneath it.

On the opposite side of this hill and at a lower elevation, the same bed of basalt reappears, and is easily recognised by its peculiar characters: it immediately encounters the still more ancient basaltic rock called the Puy de Montaudou †, and is separated by it into two branches, which re-unite below, and follow the slope of the hill as far as the level of the plain.

Few or no scoriæ are observable on the summit of the Puy de Charade, much less any thing resembling a cone or crater. The basalt contains very large crystals of augite and nodules of olivine, has a dull and leaden aspect,

* See Scrope on Volcanos, p. 142.

† The basalt of the Puy de Montaudou is very compact, fine-grained, hard, and black. It occasionally contains small granular crystals of felspar resembling those of the Egyptian porphyry, and grains of peridot. The Puy is a mere conical rock of which it is difficult to ascertain the structure, from the vegetation which clothes it. Some rude prisms show themselves at the summit; and to the west it may be seen to rest on the freshwater limestone, the strata of which are much confused at the line of junction.

is considerably decomposed, and assumes a frequent division into spheroids of a foot or more in diameter, which desquamate in concentric laminæ; yet notwithstanding these numerous characters of great antiquity, its disposition in the form of a current of lava descending from the granitic heights into the main valley below, is so evident, that M. Ramond was obliged to rank Charade in the class of modern volcanos*.

The granitic sides of the mountain must, however, have wasted considerably, and the valleys on each side enlarged and deepened themselves, since the eruption which produced this lava, which now impends over them in a rocky ledge: perhaps the convulsive shocks accompanying the production of Graveneire may have contributed to effect this; but the form of the valleys, their sloping sides, and the numerous ravines that open into them, show them to have been chiefly, if not wholly, excavated by running water. It follows clearly, then, that the main valley into which the lava of Charade descended, almost to the level of its present bottom, existed previous to the excavation of these minor valleys, and that consequently it is impracticable to assume the formation of the valleys of this district in general as constituting an epoch or marking any fixed period. Further proofs of this fact are to be met with on many points, as well of Auvergne, as of the Velay and Vivarais. Their evidence will be discussed at the conclusion of the work.

69. *Puy de la Roulade.*—A bed of basalt remarkable for its uniform separation into very complete spheroids, surmounting a small calcareous hill a few yards above the rivulet of Boiseghoux, and nearly on a level with the plateau formed by the lava of Graveneire on the opposite bank. This might be supposed part of a secondary current from Charade, but that in mineralogical characters it differs materially from the basalt of that mountain. Its little elevation above the plain demonstrates the comparatively recent date of its formation.

70. *Plateau of Chateau-gay.*—An isolated bed of basalt covering a wide extent of the calcareous freshwater formation. Towards the Limagne it rises from the plain to an average height of 450 feet; but on the S.W. the plateau formed by the lava of Jumes (16) equals it in elevation, and imitates it entirely in disposition and structure. The productive cause of the one is so evidently that of the other, that it would be impossible for incredulity itself to escape the conviction of their identity of origin. It is equally clear that the more complete insulation and greater height of the former is owing to its having been longer exposed to meteoric erosion.

* Nivellement des Plaines, 1815.

This current appears not to have had its source on the granite, but at a short distance from the limit of the two formations; and the site of its crater is still attested by the tumified and cellular nature of the basalt of the N.W. extremity, by the scoriaceous masses, and, above all, by the numerous lava-drops or volcanic *bombs*, which abound there. This is also the most elevated point of the plateau, and from hence it slopes gradually towards the S. and E. It is generally modified into rude columnar prisms, which in parts evince by decomposition a spheroidal concretionary structure, and in others divide either into massive tables or slaty laminæ, between which arragonite is often found crystallized.

71. *Plateau of La Serre* (qu. *Cheire*?).*—This remarkable current of basalt owes its interest to the circumstance of its remaining almost entire, and exhibiting in consequence that peculiar disposition which could only have been assumed by a stream of fluid matter descending an inclined plane, occupying the lowest levels, and moulding itself on the surface it spread over.

The volcanic nature of this fluid is sufficiently attested by the scoriæ upon which the actual pseudo-stratum of basalt rests, by the scorified and cavernous masses which still remain on its surface, but which adhere to and form part of the compact and solid rock below, and by the site of the vent which produced it being still cognisable on its highest extremity.

On the other hand, this basaltic bed has all the characteristic features of the more isolated and contested plateaux. Its elevation varies from 850 to 400 feet above the water channels of the valleys on either side: and a branch of it, cut off and separated from the main current by a subsequent excavation, has assumed that conical form so general amongst basaltic remains, and to which the waste of ages tends to reduce all, and crowned by a ruined fortress, called Montredon, imitates exactly the Stolpens and Kœnigsteins of other basaltic districts†.

* See Plate II.

† This process has been repeated on numberless points of Auvergne, where almost at every step we meet with isolated and conical peaks, each consisting of an immense group of basaltic columns converging towards the summit. All of these were seized on in turn for the sites of fortresses, in those times of anarchy when an inaccessible position was the necessary condition of security to person or property. Such were the castles of Mont-rognon, Montredon, Montrodeix, Mont-celets, Yodable, Usson, Nonnette, Buron, Mozun, Murol, Vandeix, Bonnevie, Mercœur, Ibois, Mercurol, &c. &c. From the number of these strongholds and the almost impregnable nature of the greater part, the feudal tyrants of Auvergne outlasted those of the rest of France; and it was not until the ministry of Richelieu, and the vigorous reign

The current of La Serre originated on the granite, and the most considerable moiety of its extent rests upon that rock, the remainder on the freshwater limestone. Its western summit, called the "Tête de la Serre," or Puy de Nadailhat, measures 3461 feet from the sea-level. It terminates to the east in a projecting tongue of hill, the point of which has suffered a partial separation from the rest. On this point stands the village of Le Crest, at an absolute elevation of 2044 feet, giving a difference of level between the two extremities of 1417 feet, with a direct distance of rather more than six miles and a quarter.

This slope is not completely uniform, but broken by three declivities which have the appearance of steps. Two of them are over the granite, and another at the line of contact of this and the freshwater formation. All are evidently occasioned by parallel inequalities in the surface below. The portion which rests on the freshwater strata is smooth and nearly level.

It is worthy of remark, that on each side a transverse ravine is found near where the sedimental beds rest on the primitive, and a depression exists on the surface of the plateau, along that line, as if already the basalt had been undermined there by an excavation sapped through the strata of friable sandstone which intervene between the calcareous formation and the granite. In time, no doubt an entire separation will thus be effected, and the eastern portion of this hill will resemble the many others around, which have lost their connexion with the primitive heights.

The basalt of this plateau, though in general amorphous or cleft by irregular vertical seams; yet on some points, particularly near Le Crest and at the Castle of Montredon, exhibits very beautiful columnar groups. It is here that the current has been eaten into by deep ravines which disclose its internal structure, and in all probability the apparent absence of this regular configuration in the remaining parts of the plateau is only superficial.

Upon the whole, this hill is interesting and instructive, as a type of the formation of basaltic plateaux in general, as one of those rare and valuable links which establish a relation between rocks apparently remote in geo-

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of Louis XIV., that a final check was given to their career of violence and rapine. Orders were then issued for the demolition of all the chateaux-forts of Auvergne, and little now remains of them but the foundations, and some fragments of their massive walls, which were generally constructed of basaltic prisms taken from the peak itself, and laid horizontally. Puzzolana was mixed with the mortar used in these constructions; and without the binding quality communicated by this ingredient, probably no cement would have taken effect on the smooth and iron surfaces of the prisms.

logical position; one of the intermediate gradations through which a current of lava occupying the bottom of a valley, passes in its slow but certain transformation into the massive and tabular capping of an isolated and lofty mountain.

72—73. *Les Côtes de Clermont* and *Chanturgue.*—These calcareous hills, once evidently united, and separated now but by a shallow ravine, are crowned with a bed of basalt, in nature and position very similar to that of Chateaugay; but its height above the plain is greater, and it has suffered more from waste, apparently in consequence of its superior antiquity.

It seems probable that this current flowed from the opposite granitic heights which rise on the N.W. of Durtol: perhaps it may have been once connected with those remnants of basalt which rest upon the granite in the vicinity of the Puy Channat, but which have lost all traces of scoriæ or cellular parts.

74. *Plateau de Prudelle.*—A mass of basalt, which crowns a granitic promontory impending over the valleys of Villar on the south and Gressinier on the north, and terminating in an abrupt escarpment towards the east. It appears, however, to have once extended some way down the steep slope in this direction, for many portions of a similar basalt are to be found *in situ* amongst the vineyards which clothe its declivity.

The cone whence this current flowed still forms a projecting knoll at its western extremity, strewed with bomb-shaped scoriæ, the cavities of which contain delicate stalagmitic concretions of quartz, the fiorite of the French mineralogists*. It is this hillock which occasioned the division of the current of Pariou (6).

At the point of contact of the granite and the basaltic bed it supports, is seen a layer of scoriæ, so far decomposed as to be cut with a knife; their cavities are filled with a white and brown bole of a waxy consistence. The basalt has separated on some points into very regular prisms of 5 or 6 sides, which exfoliate by decomposition in slaty laminæ at right angles to their axes.

Though the current of Prudelle has every appearance of being single, it consists of two very different species of basalt. That of the western ex-

* Since quitting Clermont, I have more than once regretted that during my residence there, it did not occur to me to open a trench through this diminutive volcanic cone, which scarcely rises 15 feet from the fundamental granite. It would have been interesting to examine the form and diameter of the orifice through which the lava issued, the dislocation of the granite, its alteration, &c. &c.

tremity is remarkable for the numerous and large nodules of yellow and red olivine it incloses. That to the east has in place of this mineral confused crystals of augite and compact felspar, disseminated in a base which has all the characters of a fine-grained dolerite.

75. *Puy Girou.* 76. *Puy de Jussat.* 77. *Gergovia.*—These three eminences, all based on the freshwater limestone, seem originally to have formed a single plateau, covered by a current of basaltic lava which issued from the neighbouring primitive heights and probably from the Puy de Berzè (79).

They are now partially separated from each other and from the granite; the first has wasted to a conical cluster of prisms converging towards the apex*; the second to a crested ridge; while the broad plateau of Gergovia still occupies an extended surface, which tradition and history unite to fix on as the site of that city of the Arverni which Cæsar and his legions so long and vainly besieged†.

Gergovia is as interesting to the geologist as to the antiquary; more particularly so from its offering a most distinct example of the alternation of basaltic currents with the calcareous strata of the freshwater formation. This is best visible on the eastern face of the mountain, where two deep ravines have laid open complete sections of all its beds‡.

The base consists, like the plain from which it rises, of thin horizontal strata of white marly limestone§. At about two-thirds of the whole elevation occurs a massive bed of basalt, in some parts 40 feet in thickness, which has moulded itself on the strata below, and upon the surface of which other calcareous strata have been again deposited.

* This peculiar disposition of the prisms, so evidently adapted to protect the mass they constitute from the destructive agency of rains and frosts, will be found on observation to be the cause which has preserved throughout all basaltic regions so many isolated and conical hills of this rock. I have never yet met with one of this nature in which it was not easy to trace such a structure; and this fact unites itself to the many many others presented to the eye and understanding of the geologist by every great mass of mountains, which tend to force upon him an overwhelming conviction that *the destruction of the elevated portions of the earth's crust, or in other words, the excavation of their existing valleys, has (with the exception of partial effects produced by merely local causes) been performed chiefly by the decomposing and erosive powers of the meteoric agents, combined with that of gravity.*

† Roman bricks, amphoræ, medals, and Gaulish axes and arrow-heads, in jade and serpentine, are frequently found on this plain.

‡ See Plate VII.

§ It is to the south and west of Gergovia that the thick strata of siliceous limestone containing the *Indusia tubulosa* are so abundant.

These, however, though distinctly stratified, and with a general tendency to horizontality, are far from being as regularly disposed as the inferior limestone. They are frequently distorted and confused, and occasionally interrupted by narrow horizontal veins or masses of basalt, which appear to be ramifications from an upper bed of great thickness, which surmounts the whole and forms the superficies of the plateau. The calcareous strata thus included between two decided currents of basalt, are thickly interspersed with volcanic ashes and scoriæ. A few thin strata of compact yellow limestone may be found apparently free from extraneous substances, but the general mass is rather a calcareous peperino than any thing else. It is in parts veined with semiopal, and contains masses of siliceous limestone.

The lower bed of basalt projects far beyond the upper, appearing to have been originally more extensive; and those portions which cap the calcareous hills above Aubières, Perignat, and Channonat, must have belonged to this current.

It is in some parts very regularly prismatic, in others amorphous; is of a dark colour, dense, hard, and sonorous; contains minute scaly crystals of glassy felspar, and some calcareous infiltrations.

The line of contact of this bed of basalt and the supporting stratum of marly limestone is well defined, and specimens of the smallest size may be taken from it, of which one half is compact, brittle, and black basalt, the other a white limestone effervescing strongly with acids, and apparently uninjured. The basaltic masses which occur in the intermediate calcareous strata are far from being so distinctly separated from the enveloping matter. The one substance, on the contrary, seems almost to pass into the other by a mechanical intermixture effected when both were of a very soft, if not fluid, consistence.

The upper plateau of basalt rarely presents a prismatic division on a large scale; but more frequently a tabular structure. It is on some points extremely cellular; the vesicles having been subsequently filled by crystallizations of carbonat of lime and arragonite, so as to give it the character of a very rich amygdaloid.

78. *Montrognon.*—A conical eminence of columnar basalt, crowned by the ruins of a feudal fortress, and resting on the freshwater limestone. It is probably the sole remnant of a plateau formed by a branch from the current of Gergovia.

79. *Puy de Berzè.*—A salient eminence of the granitic platform; the site of an ancient volcanic aperture, for its summit is thickly strewed with cellular basalt, scoriæ, and "bombs;" which, however, have an aspect of great antiquity. It was, in all probability, from this mouth that the currents of Gergovia, Montrognon, &c., proceeded. Their comparative elevation favours this opinion. The Puy de Berzè measures 3210 feet above the sea. The Puy Girou, 2792; and the western summit of Gergovia, 2496. Its eastern extremity is proportionately lower.

80. *Basalt of St. Genest de Champanelle.*—This current occupies the bottom of a depression in the primitive plateau through which runs a small rivulet from the village of Chatrat to that of St. Genest. In its position consequently it agrees with the lavas of the recent Puys; but since no cone remains to mark its source, and it has evidently suffered much degradation, it must certainly be prior in date to all these.

It is imperfectly columnar, and in parts separates into minute angular globules; but the circumstance most remarkable in the basalt of this current is the large proportion of *quartz* which enters as an ingredient into its composition.

This substance is very partially distributed, occurring in much greater abundance on some parts of the current than on others, and presents itself in three modes: 1. as visible grains or imperfect crystals imbedded in the base; 2. as a constituent part of that base, which observed through a weak lens appears to be a granitoidal mixture of quartz, felspar, and augite; 3. in distinct and frequently large veins, more or less free from augite, sometimes entirely pure, of a grayish white colour, and similar in disposition and aspect to the veins of quartz so common in Lydian stone, clay-slate, &c. This is the only example of a quartzose basalt I am acquainted with in Auvergne.

81. *Puy de Chatrat.* 82. *Puy de Pasredon.*—Granitic eminences capped by basalt; probably remnants of the same current; but certainly distinct from, and anterior to, that last mentioned. A. E. 2822 feet.

83. *Puy de St. Sandoux.* ("Barnère" of Ramond.)—A basaltic plateau, still more elevated, but less extensive than that of Gergovia. It might perhaps be ranked among the dependencies of the Mont Dor; but as it forms a very conspicuous object in all views of the Monts Dome, and enters into our map of this range, its description may more appropriately find room here.

It occurs on the limits of the granite and freshwater formation, resting

in part on each. More than one current appears to have contributed to its formation. That which shows itself on the surface of the plateau is remarkable for presenting a complete transition from a coarse-grained dolerite, composed of compact felspar and large crystals of augite, to a perfectly homogeneous basalt. This change is effected both suddenly, so as to enter into the compass of a small specimen; and gradually, the crystals of augite and patches of compact felspar diminishing in size, and the latter being finally superseded by olivine.

84. *Plateau of St. Saturnin.*—A basaltic bed entirely on the calcareous soil, and considerably inferior to that of St. Sandoux; but probably once a branch of the same current. On the S. E. immediately above the Chateau of St. Sandoux, a portion of this bed has assumed the figure of an enormous spheroid, composed of columns diverging from the centre of the rock, near which they are closely united, to the circumference, where a considerable space is left between them. The columns are very regular, and jointed. On other points, the basalt of the same bed exhibits a tabular configuration.

85. *Puy d'Olloix.* (A. E. 3343 feet.)—A conical eminence of basalt, which apparently is a fragment of the same current as the Puy de St. Sandoux. It incloses large knots of olivine.

86. *Chauds de Coran.*—An extensive plateau of basalt resting entirely on the freshwater strata, and overlooking the Allier from its eastern extremity. On this side, immediately above the village of Coran, rises a vast range of basaltic columns; the upper portions of which show a tendency to the spheroidal figure.

The south-western part of the plateau is covered with scoriæ and volcanic bombs, exceedingly fresh, and apparently ejected by a later eruption which burst through the more ancient basaltic currents.

A circular cavity, about 30 feet in diameter and 10 or 12 in depth, appears to be the only crater left by this recent explosion. Its inner walls are perpendicular and consist of scoriform masses of basalt, uncovered by any accumulation of lapilli or puzzolana; an inconsiderable current of very cellular lava seems to derive from this point, and covers the southern slope of the mountain. The many fragments of granite imbedded in its scoriæ demonstrate that this eruption, though undoubtedly of a much later date than the basalt which forms the surface of the plateau, had its origin beneath the limestone which supports this bed, and not within it, as some writers have suggested. It is however highly probable that the later eruption burst

from the same vent as the former, and had its focus in the mass of lava elevated into some fracture in the superficial strata at the time of the first eruption; and which, though solidified by the pressure of the rocks through which it was thrust, retained sufficient heat to discharge itself when the shocks accompanying the outbreaking of some neighbouring volcano had re-opened the fissure where it was confined. As an instance of a *secondary** eruption of this kind, occurring a very considerable time after the first, (as is proved by the lava having flowed down a steep slope into the valley, which could not have existed when the basalt now capping the hill was vomited forth,) the Puy de Coran is an object of great interest.

The scoriæ of Coran abound in octŏhedral crystals of oxydulous iron, in fiorite, and crystals of hornblende similar to those of the Puy Channat, but far larger. Some are nearly the size of the fist. They are occasionally perfect; but in general their exterior is rounded, and the angles blunted as if by a partial fusion.

87. *Puy de Cornon.*—Two remnants of a basaltic current are found upon this extensive and nearly flat calcareous hill; the remaining surface of which is mostly covered by boulders of primitive and volcanic rocks, in thick strata, and was obviously at one time the bed of the Allier, although elevated between 400 and 500 feet above this river's actual level.

To the east of the Allier a certain number of plateaux and peaks of basalt may be observed, capping eminences both of the freshwater limestone and of the low granitic range, separating the waters of the Dore and Allier, against which this formation abuts.

These are the remaining segments of very ancient currents; their scoriæ have generally disappeared; and the points they derive from, as well as their connection, if any ever existed between them, are with difficulty to be traced.

The space through which they show themselves is not very extended, and may be considered as a short band inclosed between the Allier and the meridian of Mozun. Nearly all of those remarkable calcareo-basaltic hills described above as part of the freshwater formation of the Limagne, are also found within these limits. The direction of this volcanic line seems to preserve a parallelism to that of the Monts Dome.

* See Scrope on Volcanos, p. 169.

The most remarkable of these basaltic remnants are the Puys Dallet, La Roche Noire, St. Romain, and Turluron, which are based upon the tertiary strata; and the Pics de Buron, St. Hippolyte, and Mozun, which rest on the primitive soil. They present no features of individual interest, and therefore to describe them in detail would only be to repeat what has been said already of the similar rocks in the immediate vicinity of the Monts Dome.

CHAPTER IV.

REGION II. THE MONT DOR.

§ 1. *General Outline of the Mont Dor*.*

AS yet we have found the primitive soil concealed but by occasional masses of volcanic rocks, between which it crops out at no very distant intervals. But I have now to consider one of those mountainous excrescences which have covered its surface to an extent of many miles in diameter, and elevated themselves to a proportionate height above its level.

The Mont Dor, though certainly not the most considerable of the three in bulk or extent, attains the greatest absolute elevation. Its highest point, the Pic de Sancy, is given by Ramond as 6217 feet, exceeding that of the Cantal by the trifling difference of 123 feet.

Its figure will be best understood by supposing 7 or 8 rocky summits grouped together within a circuit of about a mile in diameter; from whence, as from the apex of a flattened and somewhat irregular cone, all the sides slope more or less rapidly, until their inclination is gradually lost in the high plain around.

Imagine this mass deeply and widely eaten into on opposite sides by two principal valleys, (those of the Dordogne and of Chambon,) and further furrowed by about a dozen minor water-channels, all having their sources near the central eminences, and directing themselves indifferently to every point of the horizon. You will then have a rude, but not inaccurate idea of the Mont Dor.

It is barely possible that some mountain, not volcanic, may, by long

* The Mont Dor, anciently Mons Duranius, derives its appellation from the stream called *Le Dor* which rises on its summit, and is therefore improperly written *Mont d'Or*. See Ramond, *Nivellement des Plaines*: Mém. de l'Inst. 1815.

isolation, or accidental circumstances, have assumed somewhat of this form, but the characteristic peculiarity which the Mont Dor and Cantal share with Ætna, the Peak of Teneriffe, and all other insulated volcanic mountains, is, that the rocks of which each is composed exhibit themselves in beds every way dipping off from the central axis, and lying parallel to the sloping flanks of the mountain. This singular disposition would induce us *à priori* to conclude these mountains to be the remains of vast volcanos. The idea is of course confirmed, when we discover on examination that they consist of prodigious layers of scoriæ, pumice-stones, and their fine detritus, interstratified with beds of trachyte and basalt, which bear the stamp of an igneous origin, and descend often in uninterrupted currents, till they reach and spread themselves over the platform around the base of the mountain.

It is true that no regular crater remains on this summit. It would be irrational to expect one in a volcanic mountain which exhibits so many other proofs of having been long and violently attacked by the agents of dilapidation since the extinction of its fires.

The fragmentary ejections of its vent have gone to form the immense conglomerates that clothe its sides and accumulate at its foot. Its more durable productions, its lava currents and some consolidated breccias, have more successfully resisted, and their highest extremities still bristle in elevated peaks over a circus-like gorge, which occupies the very heart of the mountain, and was probably the site of its central crater, but which now, branching out into deep and short recesses, forms the upper basin of the principal valley, and the recipient in which two mountain rills, the Dor and Dogne, unite, at the source of the noble river which from thence-forward bears their joint names.

If the materials of a volcanic mountain were arranged in any sort of uniformity, the valleys which have reduced the Mont Dor to a mere skeleton would exhibit its constitution in the most satisfactory manner; but as might be expected, the sections they offer, disclose only vast and irregular layers of tufa and breccias, mingled with repeated or alternating currents of trachyte, phonolite, and basalt *.

* Were the causes which occasion the activity of Ætna to cease, this volcanic mountain would before the lapse of many centuries assume the chief characteristic features of the Mont Dor. Even now, its sides are furrowed by deep and vast valleys produced by earthquakes and the rapid descent of torrents of rain. The beds of lava of different epochs may be seen forming numerous pseudo-strata one above the other, and corresponding on the opposite sides of

The opposite sides of each excavation generally offer corresponding sections, the same beds being visible at similar heights on both declivities, but varying occasionally in thickness.

This is universally the case in all the narrower gorges, as well as near the base of the mountain, where the diminished slope caused the lava currents to increase in width as much as in length; and in these situations, the same bed or series of beds often extends over a surface of many square miles, forming a succession of vast platforms, with a slight and, towards their termination, scarcely perceptible declination.

On examining the currents which compose these distant plateaux, they are found to consist of basalt, which has flowed on all sides to the distance of 15 and 20, and in some instances on the east and north, of 25 or 30 miles from the central heights *. Though the continuity of some of these sheets of basaltic lava has been destroyed, we may remount many of them without meeting any interruption, till at no great distance from the summit of the group we arrive at a spot, which, from the torrefied and vesicular nature of the basalt, and the number of scoriæ and bombs still adhering to its surface, appears to be the source of the current, the vent from which it was expelled.

The plateaux of trachyte, on the contrary, rarely reach to such an extent, and few portions of them deriving from the Mont Dor are to be found without the limits of a circle of 10 miles radius. But what these currents lose in length, they make up in height and width. The lavas of this class appear to have possessed an inferior degree of fluidity to those of basalt; probably owing to their inferior specific gravity †, and greater coarseness of grain; and in consequence they have accumulated upon one another in prodigious volumes in the vicinity of the source. They thus become the

these valleys; the most remarkable of which in this respect is that of Trisoglietto. See Ferrara, *Descrizione dell'Etna*, 1818.

It appears that the flanks of the Peak of Teneriffe are yet more deeply intersected by rents and ravines; and M. Escobar is said to have counted above 100 strata of different lavas and beds of pumice on the sides of the valley of las Guanchas, N.W. of the Peak.

* These dimensions are far from being unparalleled by the lavas of modern volcanos. Sir W. Hamilton reckoned the current which reached Catania in 1669, to be 14 miles long, and in some parts 6 wide. Recupero measured the length of another, upon the northern side of Ætna, and found it 40 miles. Spallanzani mentions currents of 15, 20, and 30 miles (*Voy. en Sicile*, i. 219.); and Pennant describes one which issued from a volcano of Iceland in 1783, and covered a surface of 94 miles by 50! (*North Globe*, vol. i.)

† See Considerations on Volcanos, pp. 86, 92, et seq.

most conspicuous if not the most considerable portions of the edifice which they have reared in common with the others. Trachyte constitutes all the principal heights and central platforms of the mountain, while basalt rarely shows itself but at its foot or in the lateral escarpments and at the bottoms of its valleys.

A few isolated fragments of basaltic currents may however be seen at a considerable elevation, and resting without interposition of other substances, on some of the trachytic plateaux; while instances of so immediate a superposition of trachyte to basalt are less common. Hence it has been imagined that the eruptions which produced the lavas of this latter sort, took place after the cessation and final extinction of the volcano which gave birth to those of trachyte. But facts are far from warranting this supposition; and M. Ramond acknowledges the evident alternation of the two species of products.

Nor, indeed, are they always to be accurately distinguished from each other. Amongst the infinitely diversified varieties of trachyte to be found at the Mont Dor, where no two beds are alike, and even the same frequently changes its aspect in a considerable degree, a large proportion have the laminar structure, foliated texture, and scaly grain which characterizes clinkstone. When these, as they occasionally do, contain a large proportion of augite, they approach closely to basalt. Where the texture is not scaly, but the quantity of augite considerable, the trachytes often assume the exact appearance of some of the recent lavas of the Monts Dome, are extremely cellular, of a dark gray colour, and crystalline texture. The trachyte used as a building-stone at Mont Dor les Bains is almost identical with the lava of the Puy de Nugère quarried at Volvic.

The whole quantity of *Fragmentary* matters ejected by the principal and subsidiary vents of the Mont Dor, must once have fully equalled that of its lava currents; but the loose nature of these conglomerates has exposed them of course to more speedy destruction. The volume of those which remain is, however, prodigious. They in turns rest upon, support, and envelop the massive lava-rocks of every kind. They are found at every distance from the centre of eruption; sometimes spreading into wide plateaux, at others filling the bosom of mountain hollows, like the masses of drift snow left in a hilly country by a brief thaw.

These conglomerates are susceptible of a division into two species,

according as either class of volcanic products predominates in their composition.

Some consist wholly of volcanic ashes, or triturated pumice, in which many of the fine silky filaments of this substance are to be recognised, as well as a few crystals of felspar. This occurs either loose and arenaceous, or consolidated, by an intimate mixture with water, into a yellowish white tufa of a certain consistence and a lamellar structure, which has often been sold in commerce for tripoli. In general, however, this pulverulent substance envelops various-sized fragments of trachyte, basalt, and granite, forming a tufaceous conglomerate. As these coarser materials predominate, a complete breccia is the result, in which the fragments are immediately in contact, or separated by occasional interstices, or finally agglutinated by a cement, rarely of tufa, ordinarily of iron rust, apparently derived from the partial decomposition of the fragments themselves, which are in these instances for the most part of a highly ferruginous basalt.

M. Ramond in describing these fragmentary accumulations * very justly remarks that their disposition excludes the idea that the waters either of the sea or of inland lakes have had any share in their arrangement †; and he imagines them in consequence to have fallen from the air upon the spot they still occupy after their projection by the explosive force of the volcano.

But it will be difficult for those to coincide fully in such an opinion, who have remarked that the great proportion of these deposits are found, not in the neighbourhood of the crater, but in massive and partial accumulations at the foot of the mountain, extending frequently in a direct line to a very great distance from its centre, without altering their character, or suffering any corresponding diminution in the size of their fragments.

The conglomerates which compose the plateaux of Pardines, Nechers, and Polagnat, for example, as well as those capping the Puy de Monton,

* Mémoires de l'Institute, 1815.

† The greater number of the extinct volcanos of Italy having been apparently submarine; it follows of course that the loose matters ejected by them should have been deposited, spread out, and levelled at the bottom or on the shores of the sea: and hence the even and stratified tufas of the western coast of that peninsula, from Naples to Civita Vecchia. See Brocchi, *Suolo di Roma*, pp. 180, &c. &c. and Breislak, *Voy. en Campanie*.

But the case is very different with the volcanos under consideration, which raged upon the summit of an extensive table-land, elevated between 3000 and 5000 feet above the actual level of the sea; and whose earliest eruptions appear to have commenced not only long after this land had emerged from the ancient ocean, but at a period when most of the freshwater lakes of the district had almost, if not entirely, terminated their deposits.

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are too unequally distributed, too distant from the focus of eruption, to have been formed in the manner supposed by M. Ramond. At the latter point, which is exactly 20 miles in a straight line from the central summits of the Mont Dor, where certainly the vent which ejected them was situated, I have observed massive blocks of very compact trachyte, and trachytic obsidian, measuring more than a cubic yard in bulk. It is incredible that fragments of this magnitude should have been urged to such a distance merely by the projective power of the volcano, a power which is always exerted in a direction very nearly if not quite perpendicular. Nor could the prevailing winds, which, M. Ramond remarks, set that way, have had any notable effect upon bodies of so vast a weight. We must therefore of necessity admit the agency of some other cause in these instances; and various facts tend to prove that the rapid descent of water from the summit of the mountain at the period of its eruptions, co-operated with the fall of ejected stones and ashes in the formation of these conglomerates.

These facts are principally the following,—

1. The deposits of this nature which advance to a distance from the mountain occupy a few large valleys, obviously excavated, in the granite or the freshwater strata, previous to their formation, and are nowhere found in the wide intervals separating these valleys, as would certainly be the case had they resulted from the uniform dispersion of loose fragments ejected by the volcano.

2. Their participation in the character of alluvia is evinced in the consolidation by water and partial stratification of some of the tufas; in the occasional heaps of sand and gravel accompanying them, the trunks and logs of trees and the remains of land animals frequently found imbedded in them.

3. The greater number of fragments composing the distant conglomerates have their angles broken or rounded, and the largest are completely bouldered.

4. Immense fasciculi of basaltic prisms are occasionally seen enveloped by them. The prisms are not separated from each other, nor their angles injured. These rocks cannot have been launched thus from the crater, but must have been detached from neighbouring currents by some violent and erosive attack.

5. The conglomerates found within the limits of the freshwater formation, contain rounded fragments of limestone. These could not have been thrown up by the volcano, which broke out on the *granite;* but it is easily

seen that the calcareous strata may have been torn up by torrents hurrying along and depositing on their route the beds inclosing these blocks.

If other proofs were wanting, a strong argument of analogy may be drawn from the tufas and breccias of the Cantal and Mezen, which having suffered less degradation, afford still clearer evidence of such an origin as is here attributed to the similar deposits of the Mont Dor.

They must not be confounded, however, with the ordinary alluvial deposits of any mountainous country resulting from the abrasion of its rocks and excavation of its valleys,—from which they are distinguished not only by their volume, but by the currents of trachyte, clinkstone and basalt, which cover, support, and penetrate them in all directions, and were therefore certainly of contemporary formation.

The descent of aqueous deluges down the sides of the great habitual volcanos during the occurrence of their eruptions, is well known to be a common phænomenon *, and to be owing to one or more of three distinct causes :—viz.

1. The sudden melting of snow on the summit of the mountain, either by falling showers of red-hot scoriæ, or the contact of a disgorged current of lava.

2. Prodigious storms of rain which usually accompany or succeed to volcanic eruptions, and have been satisfactorily attributed to the condensation of the immense volumes of aqueous vapour evolved from these vents during their activity, and which constitute in fact the main agent in their phænomena.

3. The vast bodies of water, probably the contents of internal lakes, which *trachytic* volcanos, particularly those of America †, are known occasionally to eject ; and which, when mingled with the ashes and lapilli caught up in their progress, or brought with them from the interior of the volcano, have been often misnamed "currents of mud," and confounded ‡ with the product of those pseudo-volcanic explosions of hydrogen gas seen at Macalouba, Modena, in the Crimea, &c. &c. It is indifferent which of these various phænomena we suppose to have operated in the present case : possibly all may have been in turn or at once brought into action.

If we consider the effects that would naturally be produced by the

* See Considerations on Volcanos, page 158.

† See Humboldt, *Tableau Physique.* Daubuisson, *Geogn.* vol. i. p. 181. Breislak, *Inst. Geol.* vol. iii. § 641. Scrope on Volcanos, p. 160.

‡ Even by Jameson, *Manuel of Mineralogy :* 1821.

sudden rush of large bodies of water down the sides of an elevated volcano like the Mont Dor*, at its moments of eruption, sweeping away all the loose materials surrounding its crater, as well as all they meet in their descent, tearing up the flanks of the mountain, and overwhelming the plains or valleys around; we shall find them fully equal to the formation of the conglomerates that now occupy us, and which, whether filling hollows in the mountain's side, or deep and extensive valleys to a considerable distance from its base, are universally found to exhibit that chaotic confusion which we should expect from such a mode of production, and which no other can sufficiently account for.

The Puy de Monton is perhaps the point furthest removed from the Mont Dor at which these diluvial products are found in any abundance. I have mentioned its direct distance from the Pic de Sancy as 20 miles; the difference of level is about 4400 feet; a difference which affords an average fall of one foot in twenty-four, certainly sufficient to give to any great body of water the impetus required for transporting blocks of the size already noticed as occurring there.

I have been anxious to substantiate the mode of formation of these conglomerates, which has not been hitherto satisfactorily explained, on account of their forming so prominent a feature in the trachytic formations of central France; constituting perhaps in the three great volcanic groups of this class, a full moiety of their whole mass, and appertaining exclusively to these, since no similar rock is to be found in connection with the basaltic products of the more recent and minor volcanic vents.

§ 2. *Structure of the Mont Dor.*

To describe the constitution of the Mont Dor in detail, rock by rock, as far as it can be observed, would swell these pages to too great a bulk; I

* The Mont Dor is still covered every winter with great quantities of snow, which seldom disappears till late in the summer. There were some considerable patches remaining in the hollows near its summit, when I visited it in the beginning of *September* 1821. With respect to the occurrence last instanced, as taking place among the American volcanos, it is worth noticing that, like those of France under consideration, they are principally *trachytic*. The fine ashes of trachytic volcanos unite with water into a tenacious clay, which circumstance often occasions the creation of lakes within their craters during intervals of tranquillity. These lakes either burst their banks by their increasing weight, or are let loose by the next eruption, in either case rushing in a tremendous diluvial debacle on the lower grounds around the mountain.—See Considerations on Volcanos, p. 159.

refer therefore to M. Ramond's Memoir on the subject *, and content myself with sketching its principal masses, pointing out whatever is most remarkable in them.

Let us, for this purpose, imagine ourselves for a moment on the Pic de Sancy, a pyramidal rock of porphyritic trachyte, and the highest point of the whole mountain †. Connected with this by intervening ridges, rise on each side similar craggy masses of the same substance, more or less rounded by weathering, and partly covered with vegetation. Extending on our right and left, they embrace the deep amphitheatral basin in which the different sources of the Dordogne unite; presenting towards it a range of perpendicular precipices. On the opposite side each gives rise to an inclined plane with a gradually decreasing slope, perhaps broken at first into 3 or 4 step-like projections, one above the other, and by degrees widening, as it descends, into vast platforms ‡, which with few interruptions reach the base of the mountain, and prolong themselves to some distance over the adjoining country.

So general a divergence of all the principal trachytic currents from one spot, leads us to presume them the produce of a single crater, occupying this situation; and the structure of the heights surrounding the basin confirms this supposition. They consist of various and often-repeated beds of trachyte, exhibiting in their confused arrangement and scoriform parts, features which characterize the proximity of a centre of eruption. On descending we observe rocky masses of conglomerate leaning against them. Of this nature is the high ledge §, whence spring the two rivulets Le Dor and La

* "Nivellement Barometrique des Monts Dores et Domes." *Mém. de l'Acad.* 1815.

† The localities mentioned in the ensuing sketch of the Mont Dor, may be observed more clearly in Desmarest's Map, (*Mémoires de l'Academie*, 1771,) than in ours, of which the scale is much smaller. But see the bird's-eye view of the valley of the Dordogne in Plate X.

‡ The high lands of the Mont Dor, as well as of the Cantal and Mezen, are too much exposed and too elevated for cultivation, but are clothed with an unlimited succession of rich and widely-spreading pasturages. The constitution of the soil is sometimes thus concealed for a considerable space. It is, however, always disclosed at intervals in the steep banks of the water-channels which drain the plateaux. With the exception of a few fir forests in the highest regions, little wood is to be found out of the valleys; and this peculiar disposition of surface and vegetation, gives to the country an entirely different aspect according as it is viewed in its valleys or on the intervening flat-topped heights. The former are beautiful, luxuriant, and populous; the latter naked, dreary, and almost uninhabited.

§ It is amongst the debris of this rock in the ravine of the Cascade of the Dor, that erratic blocks of alumstone are found, similar to that of La Tolfa, and containing grains of sulphur.—See Cordier, *Journal des Mines*, tom. iv. 1819.

Dogne, and which unites the four chief central eminences, the Pic de Sancy, the Puy Ferrand, the Pan de la Grange, and Cacadogne. Beneath, and to the left, two deep gorges, called Les Vallées de l'Enfer and de la Cour, are completely scooped out of the same rock. It has a torrefied aspect, and consists of scoriæ and volcanic fragments both compact and cellular, united into a breccia sometimes by a ferruginous, at others by a tufaceous cement. In the former case the compound is exceedingly solid and durable. The naked peaks of the Puy de l'Aiguiller, which rises out of the Vallée de l'Enfer almost to the height of the Pic de Sancy, attest its capability of resisting exposure. These breccias are penetrated by numerous vertical dykes of porphyritic trachyte, of a dark colour, vesicular in parts, and divided into regular columns, generally at right angles to the walls of the vein. A narrow and low partition, called Les Fernes, which separates the gorges of La Cour and L'Enfer, principally consists of such a dyke. The inclosing breccia has disappeared on one side, but remains on the opposite. In the former ravine are two or three others entirely denuded, and exactly imitating the ruins of Cyclopean walls; the extremities of the prisms, which are laid horizontally, showing their polygonal surfaces on each side. The steep face of the Puy de l'Aiguiller terminating the Vallée de l'Enfer, exhibits three or four similar dykes traversing vertically its whole height (900 feet).

Immediately opposite to the Vallée de la Cour, on the other side of the Dordogne, is a deep ravine separating two craggy cliffs called Cacadogne and Le Roc de Cuzau. It is strewed with colossal ruins from the rocks above, which consist of conglomerate enveloping various currents of trachyte and basalt mingled in strange confusion. Among the blocks scattered below and belonging to these currents, are many of a trachyte approaching to obsidian, of resinous lustre and fracture, and a black colour, inclosing numerous large crystals of felspar (pitch-stone porphyry); and another rarer variety, compact, hard, of a brick-red colour, with something of the resinous gloss of pitch-stone, inclosing opake crystals of felspar exceedingly hard and of a waxy look *. The *roc Barbu*, an insulated and shapeless rock springing from the middle of the ravine, presents a cluster of diverging columns of an extremely dense, heavy, and hard basalt, inclosing large and regular crystals of augite and olivine.

* This substance has most of the characters of the trachyte or "*necrolite*" described by Brocchi, *Cat. di Rocce*, p. 158. He attributes its red colour, with reason, to excessive or long-continued exposure to heat.

Such is the nature of the area surrounded by the central trachytic summits; and in these features it is easy to recognize the traces of a vast and ruinous crater, not very dissimilar to the picture exhibited at the present moment by the recent crater of Vesuvius, torn through the bowels of the mountain by the eruption of 1822; whose abrupt and precipitous escarpments, like those of the space we have just described, are composed of a conglomerate of scoriæ and volcanic fragments, enveloping horizontal beds of lava, and penetrated by numerous dykes of the same substance, mostly vertical, and separating into horizontal prisms.

From these observations we seem then authorized to conclude the principal crater of the Mont Dor, and the vent from which issued the great formation of trachyte, to have occupied the upper basin of the valley of the Dordogne, including its tributary gorges mentioned above.

There is, however, no reason to believe that this vent was productive of trachyte alone; the numerous fragments of basalt inclosed in the surrounding conglomerates, together with the direction and slope of the neighbouring basaltic beds, tend rather to prove the contrary; and it has been already noticed that many of the currents of this rock so conspicuous on the skirts of the mountain, may be traced to various independent points of eruption on the surface of the central trachytic plateaux, which are at no great distance from the principal crater.

If, quitting the circus where the waters of the Dor and Dogne meet, we follow the torrent which bears from this point their united names *, we find perpendicular cliffs composed of repeated beds of trachyte, bounding the valley on each hand. To the left a deep ravine has laid bare the face of a steep rock called Le Cliergue, and disclosed the out-cropping of five or six immense currents of trachyte, separated from one another by layers of tufa and decomposed pumice. The lowest of these enormous beds are quarried for the building-stone of the neighbouring baths; and the rock of which they consist is excellently fitted for the purpose, separating readily into rude prismatic masses, being extremely cellular, working well under the tool, and resembling strongly the lava of Nugère or "Pierre de Volvic." Its colour is bluish gray; it has few apparent crystals of felspar, and is highly sonorous. The upper beds are of another variety, of a lighter colour, and contain larger and more numerous crystals of felspar.

A somewhat similar order of beds is seen on the opposite side of the

* See Plate X.

valley. Their upper surface slopes rapidly from the summit of the Roc de Cuzau, forming a plateau called La Durbise, which is prolonged below in the Plateau de l'Angle, immediately above the village of the Baths.

The Plateau de Rigolet obviously once formed part of this latter, though now separated from it by the excavation of the valley of the Dordogne. The height, slope, and direction of each correspond, as well as the beds of which they are composed. The upper surface of both is occupied by a thick current of trachyte, the section of which on each side of the valley presents a long range of irregular columns.

A rent worn through this and some of the inferior beds by a waterfall called *La Cascade du Mont Dor*, at a short distance above the Baths, exhibits them in the following succession *.

1. (Beginning from above) A bed of porphyritic trachyte, 160 feet in thickness, forming the floor of the plateau to its extremity. The colour of this stone varies from grayish to bluish white. It bears a considerable resemblance to the rock of the Puy de Dome, like which its fissures are sometimes lined with large blades of specular iron. It is highly porous, and contains numerous large crystals of glassy felspar, mica, and acicular hornblende enveloped in a very loose and coarse-grained base, evidently composed of the detritus of these crystals, together with grains of oxydulous iron and perhaps also augite. It resembles strongly the trachyte of *Drachenfels*. This rock often incloses spheroidal masses, of a darker colour and more compact than the surrounding substance, penetrated by interlaced acicular crystals of hornblende, which recall the similarly placed nodules of the trachyte of the Euganean Hills, and those which occur in some granites.

2. The upper trachyte is superposed to a bed of arenaceous tufa evidently belonging to the stratum above. In it are many loose crystals of glassy felspar, large and perfect, generally double. Their outside is mealy; their interior carious, often presenting longitudinal fibres separated by equal interstices. M. Ramond imagines this appearance to have been produced by a partial fusion, in the manner of the filaments of pumice; and this is certainly true of some of these crystals, which are actually passing into the filamentous state of pumice. But in others there appears to have been either a retreat during cooling, or, which amounts to nearly the same thing, a disaggregation of the crystalline laminæ during the protrusion of the lava, which in the case of these larger crystals would not be followed by

* See Plate XI.

a proportionate re-aggregation; the enveloping matrix of disintegrated crystalline matter *setting*, or hardening, before the temperature was sufficiently lowered to allow the larger crystals to be reduced to their original compactness. Similar crystals are met with in the highly porphyritic trachytes of Ischia *.

3. Columnar clinkstone, passing into basalt †, highly schistose in parts, of a dark slate colour, imbedding numerous small crystals of augite and glassy felspar. It is slightly translucent at the edges.

4. Breccia of scoriæ and volcanic fragments with a cement of tufa.

5. Thick beds of amorphous basalt, varying its characters. In some parts of a dark slaty gray colour, compact, sonorous, and containing small crystals of felspar: in others, reddish brown, heavy and close-grained, but studded with large elliptical cells, the interior of which is generally lined with small mammillæ of hematite, and the rock is throughout exceedingly iron-shot.

This bed of basalt and its accompanying breccias, make their appearance also below the hood-shaped rock of trachyte called *Le Capucin*, on the opposite side of the valley; and the columnar basalt of the *Cascade de la Querilh*, at the extremity of the Plateau de l'Angle, which appears to escape from beneath the superficial beds of trachyte and tufa, probably belongs to the same lava current; as well as those portions of this rock which show themselves in the valley of La Scie, supporting that side of the Plateau de Rigolet.

6. White pumiceous tufa enveloping a few fragments of granite, basalt, and trachyte. This bed is traversed by two or three nearly vertical veins which have evidently proceeded from the basalt above; their lower extremities are seen to terminate in the tufa. This and their insignificant proportions oppose all idea of protrusion from below ‡.

* See Considerations on Volcanos, p. 114.

† If the presence of olivine could always be detected, it might be well that this ingredient were established as characteristic of basalt, which in all its other characters is often liable to be confounded with trachyte. In an article published in the Journal of the Royal Institution for June 1826, and containing a proposed conventional arrangement for the description and nomenclature of volcanic rocks, I have ventured to propose an intermediate genus to include those rocks which partake both of the characters of trachyte and basalt, to be called Greystone (Graustein), from their prevailing, indeed invariable, tint.—The article in question was written long after this work, in which I have not made use of the term.

‡ This remarkable natural section presents itself so obviously to all the visitors of the Mont Dor, lying at the distance of scarcely a quarter of a mile from the village of the Baths, and under the Cascade which is the chief *lion* of the place, that I own myself wholly unable to

Parallel to the valley of the Dordogne, and divided from it by the Plateau *de Rigolet,* is that of a torrent called *La Scie.* The mountain that rises beyond is capped by an enormous current of porphyritic trachyte, which forms the floor of an elevated plateau called *Bozat,* the prolongation of that of Le Cliergue, and which evidently was propelled in a massive stream from the vicinity of the *Puy de La Grange,* an eminence impending over the *Vallée de la Cour.* To the west, the valley of Vandeix has divided this plateau from that of the forest of *Charlanne ;* but the perfect correspondence in slope and constitution of this and a suite of other high plains succeeding to it in the same direction, the last of which is crossed by the road from Clermont to Aurillac, prove them all to have been originally united in one of the most extensive and voluminous trachytic lava currents of the Mont Dor.

The rock of which it is composed is porous, and in parts highly cellular; the imbedded crystals of felspar numerous and large, attaining even *four* inches in length.

A flattened mountain called *Chamablanc* branches off from that of Bozat towards the north, but at a much lower level, and a bed of basalt observable on its surface and sides bears every appearance of cropping-out from below the trachyte and tufas of the upper plateau, though the debris which conceal the junction of the two rocks render it *difficult* to ascertain the fact.

On the opposite side of the valley of the Dordogne is seen another embranchment of porphyritic trachyte of still larger proportions than the one

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comprehend how M. Beudant and other French geologists could in the face of it, have denied the superposition of trachyte to tufa or basalt. M. Beudant visited Auvergne, and speaks in a tone of confidence which it is difficult to reconcile to such apparent blindness. Another equally to me unaccountable opinion of the same geologist is, that none of the trachytes of Mont Dor have the form of lava currents or sheets; which is, on the contrary, their prevailing disposition, though their bulk or thickness is so considerable as to deceive a hasty observer. M. Beudant admits, it is true, that there are *highly feldspathose lavas in the Mont Dor analogous to trachyte,* which assume the form of currents (*coulées*); but adds that the *true trachytes* are never found disposed in this manner.—The real fact is, that it is utterly impossible to distinguish, *mineralogically,* either in hand specimens, or on a large scale, the feldspathose rocks which are disposed in thick sheets and currents, from those which have a somewhat more massive and bulky figure. M. Beudant, therefore, can only intend to confine the term Trachyte to a rock of a particular figure and of peculiar geological relations,—a construction he is not warranted in putting on a term generally received in a mineralogical sense.—See *Scrope on Volcanos,* p. 94, et seq.

just described. It appears originally to have constituted a massive and elevated ridge, (similar to that of which we have seen so considerable a segment preserved in the Plateau de Bozat,) deriving from the summit of Cacadogne, and directed from S. to N. with a progressive inclination. Subsequent injuries, necessarily acting with great effect on a rock which yields so easily both to decomposition and abrasion, have reduced it to an irregular chain of round-topped hills, closely united by their bases, and gradually decreasing in height as they recede from the central summits. The principal of these go by the names of the Puys de Langle, Hautecliaux, Barbier, La Tache, Poulet, Baladou, L'Aiguiller, and Pessade. At the last of them, the trachyte abruptly terminates, exactly in face of the Monts Dome; the interval is covered by basaltic currents, most of which appear to proceed from beneath the trachyte, and to have flowed from the central vent of Mont Dor.

The plateaux also which descend towards the East from the foot of this group, as well as those on the opposite side of the valley of Chambon, which take their rise immediately from the Puy Ferrand on the very edge of the great crater, are entirely of basalt. They spread with a gradual slope, in wide and uniform sheets, over an immense tract of country; at first but slightly furrowed by the mountain torrents, further on completely penetrated to the granite beneath; and, as we descend still lower and the valleys deepen, cut up into long strips which line the margins of every gorge with massive columnar ranges, and project in the form of flat-topped promontories into the plain of the Limagne. These terminate at the Allier, but on its further bank rise some few isolated cones of the same basalt, which mark the original extent of the currents, and prove that the river had not excavated its actual bed at the epoch of their descent.

The two principal valleys that drain this vast inclined plane, viz. those of Chambon and Besse, partly excavated through granite, and partly through the freshwater formation, but every where bordered by impending ranges of basalt, are exceedingly interesting; and not the less so from the circumstance that the bottom of each has been occupied by a current of lava belonging to eruptions of a very recent date *. The upper basin of the first-mentioned valley exhibits porphyritic trachyte with its conglomerates, resting on granite † and supporting basalt; the trachyte terminates above the

* See Plate IX.

† This is the highest point at which the granitic substratum of the Mont Dor shows itself, viz. 3714 feet from the sea. It reappears on the N.E. of the mountain below *Murat le Quayre*

village of Chambon, but the tufas and breccias accompany the basaltic currents to the Allier, showing themselves at intervals throughout both valleys in prodigious accumulations, as in the Dent du Marais near the Lake Chambon, and the plateaux of Pardines and Nechers.

They universally contain blocks of every variety of trachyte and basalt, fragments of granite, pumice-stones, scoriæ, &c., and a large proportion of titaniferous iron in their sandy detritus. Masses of limestone occur in them where they rest against the freshwater strata; and in similar circumstances the basalt has sometimes its cellular cavities filled with calcareous infiltrations. At the Montagne de Laveille, near Chidrac, some highly amygdaloidal portions occur, in which arragonite and carbonat of lime form nearly two thirds of the mass.

An almost equally extensive series of basaltic currents stretches from the foot of the Puy de l'Aiguiller towards the north, reaching to the distance of 16 miles along the banks of the Sioule, and covering great part of the granitic plateau of the Monts Dome. Here, as elsewhere, they are found in association with the conglomerates, which accompany them in vast quantities almost to the end of their course. The wide basin separating the parallel granite ranges of the Monts Dome and the Puy de Banson, appears to have been once completely filled by these united volcanic products, of which immense portions still remain there. At Polognat the tufa is remarkable for consisting principally of very white and silky pumice-stones, evidently stratified by water. The conglomerates of this neighbourhood not unfrequently inclose trunks of trees, in which a complete passage may be traced from simple carbonization to the state of jet. They also contain grains of sulphur between their fibres.

The variety of basaltic currents which have taken this direction is remarkable. Near Rochefort, they form repeated and enormous beds, di-

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in the valley of the Dordogne, at the absolute elevation of 3271 feet; and on the S. E. near Chastriex, of 3422 feet. If we take the mean of these three (3469 feet) for its probable elevation beneath the central summits of the mountain, we shall have 2748 feet as the depth of the volcanic products alone on that point, and above 1400 feet for their average thickness throughout a central circle of $3\frac{1}{2}$ miles in diameter!

This volume, however considerable, is far inferior to that of the Cantal, perhaps scarcely exceeds that of Vesuvius, and sinks into nothing when compared with the colossal bulk of Ætna or the Peak of Teneriffe, which consist principally of volcanic matter from the level of the sea, and indeed from a great depth below this, to the height of 11,000 and 12,000 feet: or the still more stupendous trachytic formations of the Andes and Cordilleras.

vided into very regular prisms, or tables. The latter modification of structure is also exhibited in perfection on the border of the valley of the Sioule opposite St. Bonnet, where tabular masses are often extracted ten feet long and proportionately wide, with a thickness of but three or four inches. Their surfaces are smooth and level; they are exceedingly elastic, and ring upon being struck exactly like a plate of cast iron. The basalt of which they consist approaches to clinkstone, is fine-grained and highly crystalline, perfectly compact, of a light slate colour with a tinge of green, and totally free from any imbedded crystals, though an imperfect agglomeration of augitic particles into globular concretions is betrayed by weathering. Near Villejacques in the same valley a current makes its appearance from amongst the surrounding tufa, the basalt of which incloses brilliant laminar crystals of hornblende sometimes two inches in length, and granular ones of olivine. It decomposes into minute angular spheroids. Another neighbouring current is formed of a very fresh and cellular basalt, resembling some lavas of the Chain of Puys; another is highly impregnated with iron, black, dense, and heavy.

The Dordogne, which for the first three or four miles of its course flows nearly from S. to N., makes a sudden bend to the west a short distance below the village of the Baths, leaving to the right a massive portion of high table-land which exactly fronts the whole of its upper valley, and was perhaps originally separated from the central heights by some violent convulsion, while the subsequent excavation of the channel of the Dordogne has widened the breach.

The base of this mountain consists of various conglomerates, enveloping currents of basalt; above these a band of clinkstone may be traced across the whole of its eastern and northern faces, surmounted by porphyritic trachyte,—if indeed these two rocks do not, as might from many circumstances be suspected, pass into each other. Finally, the upper surface of the plateau exhibits more recent currents of basalt, which appear to have had their origin there.

Trachyte occupies by far the most conspicuous place amongst these component rocks, constituting the Puy Gros, an enormous flat-topped boss on the eastern summit, and descending from thence to the west in a wide unbroken platform, though occasionally covered by basalt, as far as the village of La Queuille, where the current terminates in a range of gigantic six-sided columns, some of which I observed to be not less than 15 feet in diameter; their

height is not proportioned to so great a bulk, rarely exceeding 30 feet. The rock which composes them is a dark coloured trachyte approaching to basalt (graystone), imbedding felspar and augite crystals, and exceedingly cellular. Its largest cavities often contain radiated crystallizations of arragonite.

Clinkstone, or the laminar and scaly species of trachyte, predominates to the north of the Puy Gros, where a thick bed of it seems to have been separated into detached segments by the torrent which flows from thence to Rochefort. The largest of the masses thus isolated are the Puy de Loueire, and the Roches Sanadoire and La Tuilière. At the first, the phonolite is divided into compact tables; at the two last rocks, into very regular prisms. Those of Sanadoire are entangled into fantastic groups, in one spot diverging so regularly from a common centre as to resemble a circular fan. The prisms of La Tuilière are vertical or nearly so, and schistose, splitting into thin lamellæ which at the northern extremity of the rock are at right angles to the axes of the prisms, but acquire gradually an increase of inclination, till at the other end their obliquity is such that their planes make an angle of but 15 or 20 degrees with the axes, and the action of gravity cooperates with that of the weather in separating them: the rock on this side is in consequence completely in ruins. These plates are used as roofing-slates throughout the neighbourhood, and hence the name of La Tuilière.

This clinkstone contains occasional crystals of felspar, and assumes in parts so much of the aspect of trachyte, that I am inclined to suppose it but an accidental variety of this rock, more particularly as the bed to which it belongs appears to merge in the great trachytic currents of the Puy Gros on one side, and the Puy de l'Aiguiller on the other.

The volcanic nature of the Roche Sanadoire was at one time strongly contested by naturalists, who examined the individual rock or its specimens alone, without consulting its evident connexions with those around. But the frequent occurrence of cellular portions, and occasional scoriæ imbedded in its prisms, might have sufficed to convince even these sceptics of its igneous origin. Dr. Weiss of Leipsic discovered grains of haüyne in this rock, but they are almost microscopic, and very rare.

The basalt of the high plateau now under description appears to have been produced by repeated eruptions from a vent to the N.W. of the Puy Gros, the site of which is marked out by two elevations entirely of scoriæ, called Chantouzet and Le Cros de Pèze.

Its currents have flowed both to the east and west, forming on one side the margin of the lake Guery, on the other descending into the valley of

the Dordogne, and exhibiting many prismatic ranges along its banks, as far as St. Sauve. They are accompanied by breccias, and may be observed at Murat le Quayre, le Roc de la Montilhe, and other points, to be superposed to a thick bed of scoriæ as fresh in aspect as those of any recent volcano.

The southern face of the Mont Dor alone remains to be noticed. It presents a more uniform and smoother slope than the others. The currents of trachyte have proceeded but a short distance in this direction from the edge of the great crater. Their remains constitute two or three salient masses composed of a porphyritic rock more or less porous, and in the vicinity of the crater even scoriform and tinged of a deep red colour. Basalt on the contrary is extremely abundant on this side. It descends in extensive plateaux, appearing to cover the extremities of the trachytic beds, and accompanied by a breccia of scoriæ on which it generally rests. Wherever these plateaux have been channelled by torrents, their sections offer ranges of columnar prisms of the greatest regularity; as at Chastreix, La Tour d'Auvergne, &c. At the latter spot the prisms are jointed, fitting together by means of alternately convex and concave bases; when broken they disclose a cylinder of compact and black basalt within a prismatic case of a lighter colour and looser texture.

The limits of the Mont Dor on the south are not very definite. The prolongation of its base meets that of the Cantal, and unites with it in forming a high and massive table-land, which divides the waters of the Dordogne and Allier, and is known by the name of Les Montagnes de Cèzallier. The scanty vegetation that covers the surface of this desolate and extensive district, cannot conceal the nature of its soil. It consists entirely of basalt; and its situation and aspect when viewed from the summit either of the Mont Dor or Cantal, strongly induces the supposition that it has resulted from the shock of the currents of these twin volcanos, mutually impeding each other's progress, and accumulating together into thick and almost mountainous masses.

The distance between the respective summits is scarcely 25 miles, and each volcano seems to have poured forth in these opposite directions its most copious lava-streams. Perhaps the strongest argument in favour of this idea is the complete absence of scoriæ throughout the whole of this

tract, as well as of any eminence from which the basalt could have proceeded, short of the above-mentioned mountains.

Gneiss and mica-schist make their appearance from below this basaltic district, along the whole extent of its eastern slope and at a considerable elevation, as near Anza, Apcher, &c.; and it is probable that the impediment which this high primitive ridge must have opposed to the progress of the lavas of the Mont Dor towards the east, was one of the principal causes of the prodigious volume they have acquired in this situation. I am inclined, however, to believe that the range of the Cèzallier has been considerably elevated by subterranean expansion, *since* the deposition of its basaltic covering; and this suspicion extends to the high basaltic plateaux and conical peaks which occur on the eastern skirts of the Mont Dor in the prolongation of the line of the Montagnes de Cèzallier. Such an elevation would perhaps account for the separation of the freshwater formation of the Cantal from that of the Limagne, and both may therefore, according to the idea of M. D'Halloy, have been formed in the same basin.

To the west the inclination of this elevated plain towards the Dordogne is gradual, and its surface frequently strewed with huge boulders of basalt and primitive rocks, attesting the ravages of the pluvial torrents from either mountain, and the frequent shifting of their beds.

§ 3. *Modern Volcanic Remains of the Mont Dor.*

It has been already mentioned that volcanic cones and currents, the products of eruptions comparatively recent, are found within the limits of the Mont Dor. They present exactly the same characters as the latest of those of the Chain of Puys of the Monts Dome, belong apparently to the same æra, and have burst forth on the prolongation of the same line.

Beginning from the north, the first of these cones bears the name of the Puy de *Tartaret*, and is distant between 3 and 4 miles from that of *Montenard*, the last in this direction of the Puys properly belonging to the Monts Dome.

It has been thrown up in the middle of the valley of Chambon; and, by obstructing the rivulet which flowed there, gave rise to the formation of an expanse of water, called the Lake of Chambon*, which appears, from the flat and alluvial surface of the plain above, to have been originally much

* See Plate IX.

more considerable, and to have retreated gradually in proportion to the excavation of the channel through which its excess is now discharged.

Although the hills on each side are loaded with the ancient volcanic currents of the Mont Dor, granite shows itself continually at their bases; and it is through this rock that the eruption of Tartaret has taken place, displacing and tearing up a superficial bed of basalt, which appears to have pre-existed on the spot.

The cone is composed throughout of loose scoriæ, lapilli, and fragments of granite. It has two deep and regular bowl-shaped craters, separated by a high ridge, and each broken down on one side. They have furnished together a very copious lava-current, which at first spreads over a wide and level surface, then contracting itself as the valley becomes narrower, occupies the channel of the former river, and follows all its sinuosities as far as Nechers, below which it terminates at a distance of 13 miles from its origin.

It is an interesting study to follow, through so long a course, this current of recent basalt, from its source, within an indisputable volcanic cone, along the bottom of a valley cased partly in granite, but whose sides are everywhere fringed by sections of more ancient currents, which have flowed in the same direction;—to observe the analogy of these basaltic formations of different epochs, their perfect parallelism, and almost equal extent, at least in one direction;—their frequent similarity of structure; for in many parts, particularly near Champeix and Nechers, the more recent basalt is divided into regular columnar prisms;—their common mineralogical characters; and the scoriform parts that accompany each.

There are few known countries in which such admirable juxta positions of ancient and recent volcanic products are to be found; and hence the repugnance of those, who have only examined the extremes of the series at remote spots and distant periods, to admit their identity of origin; whilst here, Nature herself has brought together the objects of comparison and placed them at once before the observer's eyes, as if for the express intention of teaching him their common mode of formation. In the words of M. Ramond, "Ce n'est assurément pas au Mont Dor que la fameuse question de la Volcanicité des Basaltes sera jamais l'objet d'une discussion serieuse!"

The village of Murol is built upon the recent current at the base of the cone, and the space covered by the lava to the south is dotted with between 30 and 40 black and shapeless eminences of scoriform basalt, which rising from an otherwise smooth surface, (for the intervening spaces have been

brought into cultivation,) offer a singular and striking picture. The form of the valley renders it extremely probable, that, at the period of the eruption of Tartaret, there existed some stagnant body of water in this corner, which would account in the simplest manner for these protuberances; it having been observed that such irregularities of surface are liable to be created whenever a current of lava meets in its progress, or rather rolls over, any marshy or moist ground: the gradual conversion of the water into steam causing a series of violent explosions, and thereby tearing and driving upwards portions of lava, which are immediately consolidated in ragged and fantastic forms by contact with the air.

The basalt of Tartaret is compact, of a harsh texture, a dark colour, and contains crystals of augite, olivine, and numerous minute laminæ of felspar. The conical eminence upon which rises the ruined castle of Murol is of ancient prismatic basalt, a detached segment of the currents which skirt the valley on each side.

The Puy d'Eraignes, seen beyond in our sketch, is of the same nature; both owe their insulated position to the confluence of mountain torrents.

Montchal, and Mont Sineire, the two recent cones which occur next towards the south, have exploded through repeated beds of basalt, and probably trachyte, at a considerable elevation on the flank of the Mont Dor.

Both have large and regular craters, and both have produced abundant currents of lava, which enter the valleys of Besse and Compains, and thread them for an extent of some miles, resting indifferently on former beds of basalt or on granite. The furious torrents of both gorges have in turn eaten out a fresh channel from the recent basalt to the depth often of 30 and 40 feet.

One remarkable and peculiar circumstance attends these cones; viz. the existence of a deep, large, and nearly circular hollow immediately at the foot of each. The bottom is covered with water, and they bear the names of the Lakes Pavin and Mont Sineire; both are bordered by nearly perpendicular rocks of ancient basalt. Their position announces them to be contemporary with the eruptions of the neighbouring cones; and it seems probable that, like the Gour de Tazana already described amongst the Monts Dome, they owe their formation to a series of extremely rapid and violent explosions.

In the same neighbourhood are four other lakes, named Chauvet, Beur-

douze, Champedaze, and La Godivel; which are probably owing to a similar cause, and date from about the same recent æra of subterranean activity.

A few other recent eruptions have taken place in various distant spots upon the same or nearly the same meridian; viz. in the neighbourhood of Coteuge, Rantieres, Brion, &c. presenting the usual characteristic products already described on so many other points, the repetition of which may be as well omitted.

They are confined to the eastern slope of the Mont Dor, and none are to be found within the boundaries of the Cantal, which is out of the direction of the line along which the most recently active vents are alone distributed.

CHAPTER VI.

REGION III.—CANTAL.

§ 1.

IN original constitution and form, the immense volcano, whose remains nearly occupy the whole extent of the present department of the Cantal, must have very closely resembled that of the Mont Dor; and the two groups, as they now exist, differ considerably in the accidental disposition and relative proportions, but scarcely at all in the nature of their erupted materials.

We described the figure of the Mont Dor as somewhat resembling an irregular depressed cone; that of the Cantal approaches much nearer to it, since its sides slope more uniformly, and are broken up by fewer, or at least narrower valleys. The chief circumstance to which the irregularities in the outline of the former mountain are obviously attributable, is the excessive bulk of the hummocks of trachyte which this volcano has pushed forth in three or four directions. The trachytic lavas of the Cantal, on the contrary, perhaps in consequence of a superior degree of fluidity, have reached to a considerable extent without accumulating into such enormous masses, and have been subsequently covered by repeated and widely spread sheets of basalt, which give to the gradually sloping skirts of the mountain a comparatively even and regular surface.

The valleys by which this surface is intersected stretch out like rays on every side from the central heights into the surrounding country; they are generally deep, and bounded by steep and rocky walls exhibiting on each side corresponding sections of the different volcanic beds through which the excavation has been effected, and, towards their termination, cutting into the primitive base by which these are supported.

Such is the case in the great western valleys of the Goul, Cer, Marone,

Mars, and Rue, which pour their waters into the Dordogne or Lot; and in that of the Alagnon on the east, the only stream which the Cantal contributes to the Allier. We have already remarked the calcareous freshwater formation, which within a very limited space is interposed between the primitive rocks and volcanic superstructure.

The lowest bed of this last order generally consists of conglomerate. It is seen at the bottom and sides of every deep valley, often constituting a vast and imposing range of turreted cliffs, which in consequence of a rude columnar division on a large scale, assume various fantastic forms. The bulk and extent of this bed are alike surprising. It is found in some valleys, that of the Cer for instance, continued with a constant thickness of some hundred feet, from the base of the central summits to the distance of more than 20 miles; preserving everywhere a gradually diminishing inclination parallel to the sides of the mountain. It universally envelops or is accompanied by currents of basalt and trachyte, which show themselves at intervals without any regularity, and are often intimately blended with the neighbouring conglomerate. The constitution of this rock is far more varied and disorderly here even than at the Mont Dor. In one spot it consists of a loose arenaceous tufa inclosing bouldered blocks of trachyte, basalt, and granite; in the next, of a consolidated ferruginous breccia of angular fragments of basalt and scoriæ, sometimes united by a cement of basalt itself, sometimes, within the limits of the freshwater basin, by a calcareous or argillaceous one. Occasionally the most decided indurated tufa containing angular fragments graduates into a compact rock inclosing small crystals of glassy felspar and augite, having a tendency to a prismatic rhomboidal *divisionary* structure, and usually stained throughout by the oxide of iron in stripes of a brown colour exactly imitating in their arrangement the undulating and parallel lines of a fir-plank*. On other points all fragments are absent, and the tufa is indurated, obviously by water, into a lamellar sort of tripoli, presenting impressions of leaves and branches of trees, and sometimes so abundantly impregnated with vegetable matter, as to become a complete lignite, which burns slowly, with an earthy smell, and is frequently used by the peasants as a substitute for better fuel.

All these different and constantly varying modifications, as well as the position and appearance of the great beds of conglomerate, are reconcileable with no other mode of production than that which we attributed to the same order of rocks in the Mont Dor. Their formation was obviously contem-

* Seemingly analogous to the regenerated trachyte observed in Hungary by M. Beudant.

porary with that of the lava-currents they envelop; but their nature and extent preclude all idea that they are owing solely to the projections of the volcano; while the great elevation which they attain round the central heights equally refutes the supposition of their being merely alluvial deposits from any body of water which may have existed at the foot of the mountain during its eruptions. It only remains then for us to conclude them the result of torrents of water tumultuously descending the sides of the volcano at the periods of eruption, in company with its lava-streams; for by this process alone, it seems, could such chaotic accumulations have been produced; in which the united agency of fire and water is marked in characters not to be mistaken.

These vast beds are usually surmounted by currents of basalt; sometimes, as in the valleys of St. Paul de Salers and Falgoux, repeated five or six times, and separated from each other only by a layer of their own scoriæ. I observed no instance of any bed of trachyte alternating with these more recent currents of basalt; and throughout the Cantal the production of the former rock seems to have ceased with that of its associated tufas and breccias, and to have been succeeded by eruptions of basalt alone.

Such is the general order of beds to be observed in their sections as afforded by the principal valleys, at some distance from the summit of the mountain. On a further ascent, the confusion of products becomes still greater, indicating the vicinity of the vent of eruption. The generally conical form of the whole mountain, and the divergence of all its currents from the neighbourhood of a few central heights, will induce us, as in the case of the Mont Dor, to presume that the volcano of the Cantal had one principal and central crater; and many circumstances unite to fix the situation of this upon the elliptical basin in which the upper sources of the river Jourdanne are first collected.

It is from the outer circuit of this area that the chief volcanic currents appear to originate.

On the east rises the Puy Griou, once evidently continued in the Plomb du Cantal, though now separated from it by a considerable depression, across which passes at present the road from Murat to Aurillac. Both are huge rocky masses of clinkstone, and seem to be segments of one enormous current directed towards the S.E. *

* The substance known in mineralogical cabinets by the name of "Pechstein of the Cantal," occurs as a nearly vertical vein in the tufa at the base and some way up the flank of the Puy Griou. It contains numerous crystals of glassy felspar, is of a deep sea-green colour, trans-

The eminence called the Col de Cabre in the same manner overlooks the source of the Jourdanne on one side, and on the other gives rise to a mountainous embranchment principally consisting of trachyte, extending in an easterly direction, and separating the valleys of Murat and Dienne; while to the N. of the same area the Puy Mari stands at the head of those massive and repeated currents of basalt, which accumulating on one another in a N.E. direction, form the Montagnes de Salers, and spread from thence over the high plain intervening between these and the Mont Dor.

With the exception of the masses of clinkstone already designated, and a vast but considerably degraded current of the same nature, which terminates in an enormous and elevated plateau above the town of Bort on the west of the Dordogne, resting on a bed of pebbles, and apparently occupying the former bed of the river which now flows more than 1000 feet below it; with these exceptions, the trachytic lavas of the Cantal are far from conspicuous, and are greatly exceeded in number, volume, and extent, by its beds of basalt which stretch in all directions from the central eminences over the sloping skirts of the mountain, and on the E. and S.W., reach to distances of 25, 30, perhaps nearly 40 miles*.

To the S.E. they form an extensive and uniform high plain, called La

lucent at the edges, of a resinous and sometimes horny lustre, a semi-conchoidal fracture breaking easily into angular pieces, but exhibiting at the same time a tendency to a laminar structure. It is certainly a volcanic production, and apparently a vitrification of clinkstone.

Haüyne is occasionally present in the phonolite of the Cantal. Large grains of this mineral were found in an erratic block on the heights separating the valley of Falgoux from that of Recusset, by Dr. Weiss of Leipsic. I searched in vain for it on this spot; but met with a remarkable species of ribboned basalt which occurs there in abundance, marked with alternate stripes of a dark and light bluish gray colour.

* Near Figeac (Department of Lot), an extraordinary rock of basalt is described as occurring at the junction of the primitive and coal formations, (Journ. des Mines, 1818, p. 43, &c.) but is supposed by M. Berthier *not* to be volcanic, from its position with respect to the coal strata indicating, in the opinion of this author, a contemporaneous formation with these. Not having visited this rock, I can express no opinion upon its nature, but I may remark that M. Cordier has recognised it for volcanic, being highly cellular, and containing green pyroxene and peridot; and that by M. Gardien it is described as prismatic, and connected with the extremity of a long range which rises gradually to the Cantal, and is every where composed of the same rock. May it not be possible that a current of lava from this volcano has here introduced itself into fissures between the sandstone strata, and that these are not necessarily posterior to the basalt, because they may be partially superposed to it? In the Bas Vivarais are instances of basaltic dykes of this nature penetrating limestone strata in a nearly horizontal direction, so as to be easily mistaken at first sight for contemporary deposits.

Planeze, reaching to the base of the primitive range of La Margeride, but little furrowed by water-courses, and of a singularly dreary aspect from its total nudity. At its extremity is seated the departmental capital St. Flour; and here, as wherever else this plateau is abruptly broken through, successive and parallel beds of basalt may be seen surmounting one another in very regularly columnar ranges.

A series of similar plateaux extends from the mountains behind Salers to the town of Mauriac, and thence some way northward. They consist principally of a light-coloured basalt, with a highly crystalline grain, sprinkled with large cellular cavities. It exhibits on different points the columnar, the tabular, and spheroidal concretionary structures; and wherever it has yielded to the erosion of torrents, is seen to rest on a tufaceous conglomerate.

But the basaltic beds through which the Alagnon has excavated its valley in the immediate neighbourhood of Murat, are the most remarkable of all for their regular columnar configuration, and perhaps also for their bulk.

They are accompanied and in part enveloped by accumulations of breccia, and associated with trachyte, but on particular points colossal portions of basalt have been stripped of these coverings, and isolated from the remainder of the current to which they belong. Such are the Montagnes de Bonnevie and Chastel. The former, at whose foot stands the town of Murat, has been long celebrated for the beauty of its columns. It is a large conical rock, about 500 feet in height from its base, composed of a single enormous bundle of prisms converging from all sides towards the apex; those of the exterior being slightly incurvated, the central ones straight and vertical. These last are the most perfect, and have been exposed by dilapidation on the eastern side of the rock. They are smooth, long, and slender, usually six-sided, rarely exceeding 8 or 10 inches in diameter, with a height often of 50 or 60 feet unbroken by joints or flaws. The museums of Paris and Lyons, as well as many private cabinets, have been enriched with columns extracted from hence; but it is a work of extreme delicacy to separate them whole from the rock, and still more difficult to convey them uninjured to any distance. This basalt is brittle, sonorous, hard, compact, fine-grained, of a dark colour, and free from any visible crystals. It is remarkable that the western face of the rock is entirely amorphous.

On the contrary side of Murat is a segment, apparently of the same bed, in which the columns are subdivided by frequent joints; the separate articulations fitting into each other by means of alternately concave and con-

vex bases, having occasionally small wedge-shaped processes arising from the odd angles of one prism, and closing over corresponding oblique truncations in the other.

In the vicinity of Aurillac * a thick bed of breccia, alternately supported, covered, and penetrated by currents of basalt and trachyte, rests upon the freshwater formation, the strata of which are in many spots twisted and dislocated exactly as if they had been still unconsolidated at the moment of their invasion by the volcanic torrents. Occasionally there are appearances of a subsequent deposition of limestone in confused strata moulded upon the rude surfaces of the volcanic beds. This may be observed between Polminhac and Yolet in the valley of the Cèr. In general, however, the line of junction of the calcareous formation and superimposed products of the neighbouring volcano is better defined; it may be followed almost uninterruptedly from Vic en Carladèz to Aurillac. The currents both of basalt and trachyte occasionally send out thick vertical veins or dykes into the limestone below; but neither along the walls of these where the contact of the two substances is immediate, nor elsewhere, could I trace any material alteration in the texture or other characters of the limestone. In frequent instances calcareous masses, as well as smaller fragments and even some freshwater shells, may be seen enveloped by the volcanic lavas, but they still effervesce briskly with acids, and except in a somewhat dusky tinge, seldom appear at all affected.

Without the limits of this formation, the primitive base emerges from beneath the volcanic products on every side of the Cantal. The most elevated point at which I have observed it is near the village of Thièzac in the valley of the Cèr, between five and six miles from the supposed crater, where a rock of mica-schist, certainly *in situ*, pierces through the trachytic breccia, and disappears again immediately.

We have no data by which to determine the relative ages of the volcanic remains of the Mont Dor and Cantal. Their lavas, however, appearing to have mingled on the high plain between them, we may conjecture that these volcanos were occasionally in action at the same period.

* It is said that a sufficient quantity of gold-dust was less than a century ago contained in the sand of the river Jourdanne to repay the labour of sifting and washing; and tradition asserts that the town of Aurillac situated on this river derives from hence its name, qu. *Auri lacus*. The trachytes of Mexico are auriferous; there is nothing therefore improbable in the idea that those of France may be so likewise.—See Brieude, *Top. Medicale de l'Auvergne*, 1782-83.

§ 2. *Canton d'Aubrac.*

The small mountainous district of Aubrac, which lies between the three towns of La Guiolle, St. Geneis, and St. Areize, in the department of Aveyron, is, I believe, for the most part covered by beds of basalt, which appear to have proceeded from a centre of eruption independent of that of the Cantal; but having had no opportunity of observing this group otherwise than from the summit of the latter mountain, I am unacquainted with the true limits and disposition of the volcanic productions. The accompanying map must therefore be considered as defective on this point, and the blank will remain to be filled up by some future observer.

CHAPTER VII.

REGION IV.—DEPARTMENTS OF THE HAUTE LOIRE AND ARDÈCHE.

§ 1.

THE basaltic ramifications of the Cantal impeded in their progress to the East and S.E. by the high primitive range of La Margeride, escape to the North of this, and extend nearly to the banks of the Allier in the direction of Lempde and Brioude. On crossing the river *, and penetrating further into the department of the Haute Loire by the high road to its capital, Le Puy en Velay, we first traverse a barren tract of primitive soil, appearing to have been much devastated by torrents descending from the heights of La Chaise Dieu; and immediately find ourselves surrounded by volcanic remains of a different character to those we left behind on the other side of the river, and evidently foreign to that focus of eruption. The Allier may therefore in a general way be established as the natural boundary of the volcanic districts of the Cantal and Haute Loire.

The volcanic remains of the departments of Haute Loire and Ardêche, or in other words, of the ci-devant provinces the Velay and Vivarais, belong to both the classes which have been distinguished above, and accordingly arrange themselves under these separate heads,

* However foreign to my subject, I must be allowed to mention, as an object of curiosity but little known, from this road being unfrequented by curious travellers, the bridge over the Allier at Vielle Brioude, one of the noblest and most beautiful works of the sort in Europe. It consists of a single stone arch, with a span of 192 feet, and rising 90 from the river. It is perfectly level at top, and, though narrow, admits of the largest carriages. The piers that sustain this magnificent arch abut on either side against rocks of mica-schist which here encase the Allier for some distance. It was built as early as the 14th century; but it is only within a few years and under Napoleon that it has been widened to admit vehicles of all sizes. The airy lightness and elegance of the arch as seen from below is not perhaps to be paralleled by any other similar piece of masonry.

1. The Mont Mezen and its dependencies.

2. The products of more recent eruptions, which have burst out on numerous points irregularly scattered over a broad band of the primitive plateau, from Paulhaguet and Alègre to Pradelle and Aubenas, seeming to be a prolongation of the chain of recent volcanos already described in the department of the Puy de Dome.

§ 2. *The Mont Mezen and its Dependencies.*

The Mont Mezen is the most elevated of an extensive system of volcanic rocks resting partly on granite or gneiss, and in part on the Jura limestone, and which by their mutual connections in position and constitution are demonstrable to be the remains of a single and powerful volcano, of the same character as those which we have noticed in the Mont Dor and Cantal. Its products, however, though similar in substance, are disposed in a somewhat different manner from those of the two other volcanos, being spread over an equally extensive surface without accumulating into such mountainous masses around their centre of eruption. Two obvious causes seem to have contributed to occasion this diversity of aspect, viz.

1. That the eruptions of this volcano appear to have been less frequently repeated than in the former instances:

2. That having burst out on one of the highest eminences of the primitive plateau, which afforded a considerable slope in most directions, its lavas abandoned the vicinity of the vent immediately on their protrusion from it.

Owing to these circumstances the fundamental granite is disclosed occasionally in ravines even up to the foot of the central summits; and the highest of these, the Mont Mezen, though raised on a much more elevated basis than either the Cantal or Mont Dor, is inferior to both in absolute height. It measures from the sea according to Cordier 5820 feet.

The Mezen itself, and the other principal masses grouped around it, are uniformly composed of clinkstone, (phonolite, scaly or schistose trachyte,) a rock which ranks first amongst the products of this volcano; while the common or massive variety of trachyte is, I believe, totally absent throughout the whole system. Basalt also occurs in great abundance, and is associated with vast beds of its peculiar conglomerates, analogous in their general characters to the same formation in the Mont Dor and Cantal, but, owing to the non-production of trachytic lavas, with a minor proportion of

pumice in their composition, and consequently almost always in the state of basaltic breccia (basalt tuff).

We shall be fully justified, by the universal declination of these different volcanic beds from the Mount Mezen, in fixing the site of their vent of production in its immediate proximity; and on the S. E. of this rocky eminence there still exists a semicircular basin whose steep sides are entirely formed of scoriæ and loose masses of very cellular and reddish coloured phonolite, and which probably therefore formed a part of the circuit of one of the last formed craters. As I had unfavourable weather for visiting this bleak and desolate district, my observations were necessarily limited, and I was unable to ascertain the existence of any more such cavities. From this spot two principal embranchments of clinkstone are projected, one to the S. the other to the N. N.W.

The first shows itself in between twenty and thirty neighbouring rocky eminences of very considerable magnitude, and more or less degraded to a conoidal form, studding irregularly the high platform of the Haut Vivarais. From the foot of one of these, called Le Gerbier des Joncs, gushes the source of the river Loire.

The second constitutes a mountainous chain of numerous similar rocks, connected in general by their bases, covering a wide band of country as far as the towns of Roche en Regnier and Beauzac on the further side of the Loire. The uniformly progressive declination of this series of phonolitic summits from the Mezen to the bed of the river, where they terminate, the two last leaning against the foot of the primitive range of La Chaise Dieu on the *opposite* bank, proves them in my opinion to be the remains of a single enormous lava current, prior in date to the excavation of the actual channel of the Loire, and far the most considerable in bulk and extent of any I have had occasion to observe in the Phlegræan fields of France. The space it appears to have covered is more than 26 miles in length, with an average breadth of 6, containing therefore a superficies of 156 square miles. Its thickness must have originally been prodigious, and may be judged of by the mountainous portions still remaining, whose outline is to be seen in the accompanying panoramic sketch *. Many of these rise to a height of 400 and 500 feet from their base; and none, I believe, show any marks of a division into separate beds; so that the whole colossal range must be supposed of a piece, the result of an individual eruption.

* See Plate XII.

It rests generally on granite, either immediately, or with the intervention of basalt; but appears also to have covered a large angle of the calcareous freshwater formation which we have already described as occurring in the neighbourhood of Le Puy.

As the relative ages of these two deposits may be considered an object of considerable moment, I took some pains in examining their line of junction. On different points near the villages of St. Pierre Eynac and Mercœur, the clinkstone has every appearance of resting partly on the freshwater strata. Immediately below the latter village, which with the ruins of its castle is built on a conical peak of clinkstone, the superposition is decided and immediate. It is true that the nucleus of this and all the other isolated hills capped by phonolite which I observed within the limits of the freshwater formation, is of granite; and the great inclination of the calcareous strata of Mercœur at the point where they support the clinkstone, indicates the granite against which they abut to be at no great distance. But it is not difficult to conceive that by this subjacent primitive nucleus alone the capping of clinkstone has been preserved from destruction; nor is it strange, *à priori*, that this rock should not yet have been found resting *solely* on the calcareous strata, for the reason that the latter, consisting in this quarter of very soft and friable clays or marls, may be supposed to have every where yielded to the erosion of the pluvial waters, to which the highly fissile structure of the superincumbent rock would give an easy access; and owing to which, the whole of the clinkstone bed which covered these soft freshwater strata was probably soon undermined, precipitated, and swept away; with the exception of such portions as were accidentally based upon some primitive knoll protruding through the marls, as appears to be the case in the instances quoted.

In fact, the most friable of the freshwater strata, the clays and marls, have generally disappeared; all but a few scattered patches which lean against the primitive edges of their basin, or those portions that were protected by a cover of basalt and its indurated breccia, which being less permeable to water than the fissile clinkstone, have remained longer on their treacherous foundation: but even these are reduced to comparatively small segments of beds originally very extensive, and annually suffer more or less diminution by the sapping and mining of their base.

The fact, however, that the clinkstone has only been observed resting on the calcareous strata in the immediate vicinity of granite, might be imagined to throw an appearance of ambiguity on the reality of this superposi-

tion, were it not confirmed by a negative proof of the strongest nature, viz. the total absence of clinkstone fragments * among the transported materials of the freshwater formation, or the sands and sandstones that underlie it; while on the contrary they abound in the alluvia and volcanic beds which were deposed upon these after they had been considerably degraded. It is scarcely possible that the bed of clinkstone could have been worn down to the insulated peaks now existing, before the deposition of the sands and marls, without a fragment or a pebble of it being found in these strata to attest its destruction.

MM. de Humboldt and Daubuisson have remarked the tendency of phonolitic mountains to waste into detached masses of a conical form. No where could the truth of this observation be better appreciated than along the range that now occupies us, which is entirely reduced to a series of rocky eminences, presenting every intermediate gradation of figure from the rude segment of a bulky hummock to the perfect cone.

The cause of this uniformity clearly lies in the much greater facility with which this rock yields to meteoric influence on some points than on others, as well from its frequent differences of texture and consequent aptitude to decomposition, as from its accidental varieties of structure; the columnar and laminar modifications at times combining to hasten a disunion of parts (as was remarked in the Roche Tuilière, Mont Dor), at others to afford the utmost power of resistance, as when a parcel of columns leaning against one another converge into a conical cluster. The same causes continue to influence the aspect of the mass after it has been completely isolated and reduced to a rounded form by the wasting of its angular projections. Where the phonolite is of a quality that readily decays on exposure, it presents a smooth-sided cone, clothed with a thick layer of white earthy soil, which frequently supports luxuriant forests of oak and fir. Where the rock is less destructible, its upper outline is cap-shaped, notched and craggy, and its base encumbered with barren and ruinous piles of slaty fragments. The clinkstone both of the northern and southern embranchment from the Mezen is always, I believe, laminar, often rudely columnar. The laminæ vary from massive and compact plates of great

* It may appear presumptuous in a passing traveller, whose observations must have been limited in time and number, to make an assertion of this general nature; but for this fact I have the authority of M. Bertrand Roux, a gentleman constantly resident at Le Puy, and assiduous in his examination of the freshwater formation of that neighbourhood. See his work *Sur les Environs du Puy en Velay*. 1822. Paris.

size and thickness, to thin slates; the latter are in general use throughout the country for roofing. Its colour varies from dark bluish gray to grayish green, green, pale or ochrey yellow, and pure white.

The lighter tinted varieties generally occur at the bottom of the bed, never, I believe, in the upper and more exposed parts; they must not therefore be confounded with the ordinary effects of decomposition. The dark coloured species are compact, hard, and translucent at the edges, their fracture straight and splintery; the pale parts are more granular, earthy, and approaching to common trachyte, not unfrequently of a very scaly texture, and a mild silvery or pearly lustre. Sometimes globular concretions of a dark greenish hue appear thickly disseminated in a base of a lighter and grayish tint. These are evidently owing to the imperfect aggregation of augitic molecules, which under more favourable circumstances would have united into distinct crystals.

Small imbedded crystals of felspar are frequent, of augite or hornblende rarer. The lower parts of the bed are somewhat porous and occasionally vesicular: in the vicinity of the central summits highly cellular and even scoriform masses are abundant, they are usually of a reddish or reddish blue colour, and a crystalline texture.

Basalts and Breccias.

We have already noticed basalt as having been largely produced by this volcanic system. The currents have principally flowed towards the N.W., W., and S. E., led by the superior inclination of the primitive platform in these directions.

Towards the S.E. in particular an immense embranchment, composed apparently of two or more successive beds of basalt accompanied by breccia, descends to a distance of more than 30 miles, rivalling in extent and volume that of clinkstone which we have described on the opposite side.

This current is not less interesting from its position than the magnitude of its dimensions. It appears to take its rise from beneath the scattered peaks of clinkstone which have been noticed above as grouped together on the South of the Mezen, and is prolonged with a gentle slope towards the S. W. for the space of about 12 miles, resting on the high primitive platform of the Haut Vivarais, and forming an elevated ridge which separates the waters of the rivers Ardêche and Erieux. Near the line of junction of the primitive and secondary formations it is abruptly broken off by a deep

gap, through which passes the road from Aubenas to Privas. But on the opposite side of this depression the same bed is repeated at a precisely corresponding height on the summit of a mountain of Jura limestone. From hence it is continued with a similar gradual inclination to a direct distance of about 12 more miles. As long as this bed is based on granite its breadth is trifling, and it shows itself rather as a continuous flat-topped mountain crest, than in the usual form of a wide plateau. But on entering the limits of the secondary formation it assumes a different disposition, spreads itself to a width of 5, 7 and 9 miles, and covers an extensive and elevated limestone district, which under the ancient regime went by the name of the Coiron. There cannot be the least doubt but that the whole of this lofty tract has been solely preserved from destruction by its volcanic capping. The remainder of the limestone formation around has been eaten into in all directions by various mountain torrents, and gnawed down by meteoric abrasion to a far inferior altitude. The Coiron alone beneath the shelter of its basaltic coating has effectually resisted, and juts out like a huge flattened head-land from the margin of the high primitive plateau into the southern plain. It has not, however, escaped uninjured. The agents of waste, to which the iron hardness of basalt itself ultimately yields, have intersected it by numerous transverse ravines, excavated sometimes to a considerable depth through both the volcanic and calcareous strata. They are separated by massive parallel embranchments, which derive from a straight longitudinal axis, exactly in the manner of ribs from the spine. On either side there are as many as eight or nine of these, each crowned by a prodigious tabular load of volcanic products, presenting in its section a vast range of vertical cliffs resting on the secondary limestone strata. The perfect correspondence in position, structure, and dimensions, of these cappings, as well as their all branching off from the same stem, testify to their having been once united in a single continuous platform; and in all their aspects, but particularly from the side of Villeneuve, where the extremities of 6 or 7 of these ramifications may be taken in at once by the eye *, their appearance is striking in the extreme.

The thickness of the volcanic mass is usually between 300 and 400 feet, which appeared to be made up, wherever I examined it, of two enormous distinct beds of basalt, separated by a layer, varying greatly in thickness, of scoriæ and volcanic fragments united into a breccia, or of loose scoriæ

* See Plate XIII. Also the General Map of Central France.

alone. Each bed, but particularly the inferior one, presents a sort of lower story of very perfect and well-matched vertical columns, surmounted by a still thicker mass, which is comparatively amorphous, but on a near approach is seen to consist of innumerable small columns both straight and incurvated, disposed in every possible direction, and entangled into every variety of figure. These two portions are blended at their line of contact in such a manner that it is impossible to doubt their belonging to the same bed. The basalt of the uppermost surface is porous, slaggy, and scoriform.

The almost architectural symmetry resulting on many points from this arrangement was probably the origin of the fable current among the peasants of the plain below, who still call these rocks "Les Palais du Roi," and imagine them to have been reared and inhabited by some giant monarch.

The limestone which supports them is in parts clayey and friable, passing into and alternating with shale, and consequently yields easily to abrasion. The superincumbent cliffs are thus frequently undermined, and huge portions detaching themselves, roll or slide down the shelving and slippery sides of the calcareous bases, which are in some parts thickly strewed with their ruins. Many of these precipitated masses consist of parcels of very regular prisms, and of such large dimensions as to induce M. Faujas to give an engraving of them *.

The remarkable rock on which stands the castle of Rochemaure on the banks of the Rhone (also engraved in the above work), as well as two others in its vicinity, are evidently the extreme segments of one of those arms which the principal basaltic trunk of the Coiron stretches out towards the East; they appeared, however, to me not to be in their natural position, and perhaps descended by a slip or subsidence from the cliffs above, in consequence of the excavation of this part of the valley of the Rhone.

Not far from the extremity of one of the lateral embranchments, on the opposite side, at Villeneuve de Berg, may be observed an extensive dyke of basalt traversing in a direction nearly N. and S. the strata of secondary limestone which compose some low hills at the foot of the Coiron. This is mentioned by M. Faujas, and his description of its position is sufficiently accurate; the basalt is both cellular and compact, very dark coloured, dense, and crystalline. The compact parts sometimes affect a globular form, at others break into rhomboidal pieces. The cavities of the cellular parts are often filled with calcareous infiltrations. The limestone shows few marks

* Volcans Éteints du Vivarais et Velay.

of alteration by contact with the basalt, nor do its strata appear disturbed or shifted; specimens may be broken off presenting both substances firmly united. There seems no reason to doubt that this vein proceeded from an overlying mass of basalt now destroyed, the prolongation of that above St. Jean. The enormous fragments which still strew the valleys of the Laduegne and Escoutay, are sufficient to prove that the bed did not originally terminate at its present limits in that direction.

It is almost needless to mention that the ravine called Les Balmes de Montbrul, and others in which M. Faujas saw the frightful abysses of a volcanic crater, are merely accidental excavations in the basalt and scoriaceous breccias of this bed.

On the whole, there are many circumstances, besides their immense bulk, attending the currents which constitute this bed, that render them in a geological light perhaps the most instructive of any in the interior of France *. Their disposition at first in a narrow ridge across the primitive heights, then in a widely-spreading sheet over the secondary formation, perfectly parallel to its strata, and every-where preserving the same gradual declination from the neighbourhood of the Mezen to the extremity of the Coiron, evidently demonstrates their having flowed at an epoch when the surface of the primitive plateau was directly continued in that of the secondary strata; and appears to indicate that this last formation at least was at the time in a state of integrity.

That it had however long emerged from the ocean in which it was deposited, is attested by the circumstance, that M. Beudant found beneath the basalt a vegetable soil containing terrestrial shells of a species still existing in the same country (cyclostoma elegans).

The immense quantity of matter which has been abstracted from the secondary district since the epoch at which this lava was emitted, cannot but strike us with astonishment. There can be no doubt that the surface on which the basalt of the Coiron rests, was at that period the lowest of the neighbouring levels, or these repeated currents of liquid matter would not have flowed in its direction; yet at present this same surface vastly overtops every other height of the same formation, and ranges upwards of a thou-

* The nearly horizontal disposition and enormous dimensions of this basaltic formation, the double order of columns displayed in its sections, its position upon limestone strata, into which it appears to have injected veins or dykes of its substance, &c. will perhaps render it more analogous to that of the N. E. coast of Ireland, than any other known and undisputed volcanic district.

sand feet above the average level of the basins of the Ardêche and Rhone on either side. That a considerable proportion of this vast amount of excavation was effected by meteoric agency such as is still in operation, is a fact susceptible of direct proof, as will appear from the volcanic formations of the Bas Vivarais. To attribute the remainder to any other cause of an hypothetical nature unsupported by evidence, either direct or analogical, would be most unreasonable.

We now proceed to the other basaltic remains which owe their origin to the volcano of the Mezen. They form the covering of a very extended surface of the Haut Vivarais and Velay, but from their situation on so elevated and exposed a region, have been intersected in all directions by the channels of mountain torrents, so as to disclose the subjacent rock, which is every-where granite, except within the boundaries of the fresh-water formation of Le Puy.

It is remarkable that detached plateaux of basalt are scattered profusely near the borders of the great phonolitic embranchments noticed above. Not unfrequently the interval between two or more conoidal rocks of clinkstone is occupied by a flat superficial bed of basalt extending quite up to their bases; and it is very difficult, in consequence of the excessive degradation of the clinkstone and the piles of debris which gather round their skirts, to ascertain whether the basalt passes below them, or has been deposited since their separation. The former conclusion is however rendered most probable by all the accompanying circumstances.

The basaltic beds which flowed eastward from the Mezen have been reduced to a few scattered patches by the same causes which have cut up and ravined to a great depth that barren and dreary primitive canton called Les Bouttières. Those which took their course to the E. and N. E. are more entire, descending into and traversing the valley of the Loire, accompanied by large accumulations of conglomerate. I think it evident from an attentive examination of this tract, that the basin of the freshwater formation at the period of its invasion by these volcanic products had been laid dry, and was even partially eaten into by the torrents that descended from the environing heights: that the position of the river which then effected its drainage and received these streams, was very much to the west of the actual channel of the Loire, and at the foot of the western range of mountains: and that in this state of things the whole of the basin up to that range was deluged by vast currents of basalt, which flowed from the vicinity of the Mezen in company with an immense quantity of fragmentary materials,

transported by torrents of water and deposited in the same disorder as the conglomerates of the Cantal and Mont Dor.

The facts on which this opinion is built are contained in the following observations, which will be made much clearer by the accompanying panoramic sketch of this district *.

From the centre of the volcanic system near the Mont Mezen vast beds of basalt are seen to stretch with a gradual inclination over a wide surface of granite, towards the W. and N. W. On attaining the freshwater formation they are prolonged over it exactly in the same manner, without any material change in the angle of their slope, and few complete interruptions to their continuity. Where these do occur, the original union of the different segments is evident from the corresponding altitude, disposition and nature of the masses which border either side of the valley. In this way they extend to a considerable distance beyond Le Puy; and though towards the extremity of their course they have been themselves covered by more recent and scarcely less copious lava streams from a different source, they may still be universally recognised by their peculiar characters, along the mural flanks of the numerous ravines which intersect this plain, almost up to the base of the western granite range.

While describing the freshwater formation of Le Puy, I spoke of it as arranged in strata having a progressively decreasing dip from the granite against which they lean. It is remarkable that the volcanic beds are not parallel to the planes of these strata by which they are supported, but cut across them irregularly, and often very abruptly; as for example in the Montagne de Douc, where the dip of the clays and marls is scarcely 10°, while that of the superposed bed of basalt and breccia is in some parts 40° and 50°†.

Nor do the volcanic beds in general rest immediately on the calcareous

* See Plate XII.

† It is worth remarking *en passant*, that these blue and white marls are the "basalts decomposed by sulphureous vapours" of M. Faujas. This is a strange error; but it must be owned they resemble volcanic substances fully as much as the quartzose sandstone of Brives, which in this author's eyes was of the same nature. Faujas affords a striking example of the danger of handling any branch of natural history without a personal and practical acquaintance with the subjects discussed. A blind man who should indite a treatise on colours would be not more liable to err than was Faujas when he composed a bulky folio on volcanic rocks, never having seen a volcano. In the same spirit, though in the opposite extreme, wrote and argued the Wernerians when—but no—let me not recall those errors, of which the supporters are, I believe, at length most sorely ashamed.

strata, but with the intervention of a layer of clayey and micaceous sand mixed with volcanic ashes, and the debris of primitive and volcanic rocks, particularly rolled fragments of clinkstone. This stratum is not parallel to those of the freshwater formation on which it rests, but to the volcanic beds by which it is covered, and was apparently deposited in the channels of various rivulets which flowed over and had already deeply excavated the soft calcareous strata below. It generally incloses vegetable remains, slightly carbonized, and on certain points so abundant that this alluvium passes into a lignite, of which some beds are occasionally of sufficient thickness to become the object of extraction, as at Aubepin and La-roche-lambert. The plants are either reeds and grasses, or leaves, twigs and branches of dicotyledonous trees. I found amongst them a bone totally unmineralized appearing to belong to a large bird, and M. Bertrand Roux showed me a fragment in a similar state which he had extracted from the same stratum. It measured 10 inches in circumference, and resembled a portion of the tibia of some large animal. Hollow kidney-shaped balls of clay iron-ore frequently also occur in the same bed. Where this intermediate layer is absent, and the volcanic products rest directly on the freshwater strata, the line of contact exhibits a breccia of scoriæ and puzzolana inclosed in a calcareous or argillaceous paste, such as has been remarked in parallel situations in Auvergne. In some cases this breccia appears to proceed in part from decomposition of the volcanic beds above, and would be classed mineralogically as a wacke. It is remarkable beneath the mass of basaltic breccia called Les Rochers de Peylenc, for containing numerous nodular blocks of olivine of an extraordinary size. One of an oval shape which I measured was five feet in circumference, many others around were nearly as large. These masses are rounded as if from bouldering; yet those which are imbedded in the basalt above have the same figure*; they break easily into angulo-globular pieces, and are of a transparent light green colour irregularly spotted with a darker green when unaffected by decomposition; those in which this process has begun are more friable and opake, and of a dull yellow or orange hue.

The same hill is interesting from the circumstance that the river Sumene, which seems once to have flowed in a different direction, has evidently eaten its present channel through the clayey marls supporting this great bed of basalt and breccia, part of which has been in consequence precipitated.

* They have in fact been rounded by the internal friction of the lava which inclosed them, as it flowed onwards in a state of imperfect liquidity. See Scrope on Volcanos, p. 104.

The piles of rocky fragments, which the river alternately dashes over and dives between, with the formidable walls rising on each side, adorned with magnificent columnar ranges, and almost closing over the darkened gorge, form a striking scene of ruinous grandeur.

The volcanic bed itself wherever it appears may be considered as an extensive tabular mass of indurated breccia from 100 to 300 feet thick, in turns supporting, overlying, and enveloping currents of basalt, which at times diminish to the dimensions of a narrow vein, at others swell out into the amplitude of an enormous bellying mass. In the latter form they have been frequently stripped of the inclosing conglomerate, and appear as shapeless and almost isolated rocks.

The breccia is at times stratified, and has often a tendency to a rude columnar configuration. It consists of both angular and rolled fragments of volcanic rocks of many kinds, of granite, gneiss, and mica-schist, and occasionally of marly limestone; the volcanic of course predominating. The cement is generally of volcanic ashes, hardened by water and pressure, participating but little in the pumiceous nature of tufa, and passing into an arenaceous compound, the detritus of the rocks whose fragments it incloses. Sometimes the gluten is merely an oxide of iron, at others basalt itself fills the interstices of the broken materials, appearing to have enveloped them in a state of fluidity.

The basalt varies in character in different parts, seeming to belong to separate currents. It is however generally columnar; often presenting the greatest accuracy of design, as in the rock called "Les Orgues d'Expailly," in that behind the mansion of Douc, and on numerous other spots along the valleys of the Loire and its feeders. On more than one I have observed the three chief modifications of divisionary structure,—the columnar, tabular, and spheroidal,—distinctly exemplified in the different parts of the same mass, and passing into one another. Its mineralogical characters are extremely diversified. Sometimes, as we have seen, imbedded knots of olivine predominate, sometimes crystals of augite, of hornblende, or of glassy felspar. Many varieties are much iron-shot, and then black, compact, hard, and sonorous; others have almost an earthy feel, the colour of a dead leaf spotted with bluish gray, are porous, and decompose rapidly, separating into angular globules. Such is that which occurs on each side of a small ravine running up from the village of Expailly near Le Puy, to the foot of a hill called Le Mont Crousteix, and which contains the far-famed zircons, sapphires, and garnets of Expailly. They have been for-

many centuries found in the sand of the streamlet called Rioupezzouliou, that drains this ravine; but it is only of late that they have been detected in their matrix, which is the above-described basalt. The zircons occur in small imperfect crystals, and are collected in such numbers that I have seen a large drawer full. The sapphires are next in abundance, and are found in hexahedral prisms rarely exceeding three lines in diameter. The garnets are scarce, and in rhomboidal dodecahedrons, usually about the size of a large pea. But all these crystals, not only when taken from the alluvium of the ravine, but those also which are imbedded in the compact basalt, have lost the sharpness of their angles, and are in general much defaced. There is, indeed, every reason, from their aspect and mode of setting, to suppose, that their crystallization was not contemporaneous with that of the felspar, augite, and olivine which they accompany, but preceded it, and that these minerals resisted the fusion to which their original matrix was probably subjected before its conversion into a basaltic lava.

Both basalt and breccia occasionally envelop irregular deposits of volcanic ashes having the appearance of desiccated clay; and this substance, where in contact with the basalt, is divided to the depth of about a foot into very regular columnar prisms, perpendicular to the surface of the basalt with which it is in contact, and whose most general mode of structure it accurately imitates in miniature. It is often of a fine texture, and a rich salmon colour; sometimes graduates into a micaceous sand the detritus of volcanic and primitive rocks, similar to that which occasionally forms the paste of the basaltic breccia, and on other points into a conglomerate of bouldered pebbles.

The valleys worn through this vast volcanic bed offer here, as in the Cantal, an extraordinary series of pictures. The breccia, where it is much impregnated with iron, or otherwise considerably indurated, has resisted the agents of erosion, and remains in isolated masses of grotesque forms. Such is the Rocher de Polignac, that called Corneille, whose calcareous base is half-incircled by the town of Le Puy, and that of St. Michel, a needle-shaped and picturesque pyramid, crowned by a church, of which a tolerable engraving is given by Faujas de St. Fond, who supposed it to have been shot up from below by a volcanic eruption, and consolidated in its actual form *.

* How many conflicting and wonderful theories might naturalists have spared themselves the pains of inventing and propagating; how many puzzling and hourly accumulating facts might even now be simply and satisfactorily accounted for, would we but consent to allow its

In frequent instances the basaltic beds of this neighbourhood have sent forth veins or dykes into the subjacent strata, whether breccia, limestone, or granite. Examples of the first kind are exceedingly common; one of the second may be observed at the foot of the hill called Brunelet, on the left of the road from Le Puy to Issingeaux. The dyke proceeds from a mass of basalt, and cuts vertically through strata of marly limestone. Its termination is not visible. The road from Le Puy to Rozières on the descent towards Mercœur, is traversed by a dyke of basalt about a foot and a half wide, and which can be traced only about seven or eight yards in length. It occurs exactly where the marly strata lean against the granite, and appears parallel to the plane of their junction, which is elevated at an angle of about 60° from the horizon. One wall is unaltered granite, the other a narrow stripe of granite bleached and disintegrated to the state of gravel, intervening between the basalt and the calcareous strata. The basalt is accompanied by scoriaceous portions, and from its similarity of texture, and other mineralogical characters, as well as its position, appears to have derived from a conical mass capping the granite at a higher elevation.

The side of a narrow ravine at a spot called Les Pandrèaux, between Lantriac and Le Puy, presented me with another nearly vertical basaltic dyke three feet wide, cutting through granite, which is considerably altered along the line of contact; and at no great distance in the same valley rises the Roche Rouge so strangely accounted for by M. Faujas. It is in fact nothing more than a "renflement" or bulky part of a basaltic dyke, which from its hardness of substance and solidity of structure has resisted the abrasion that has gradually worn away the granite around (of a very friable quality); from which it now protrudes to the height of about 60 feet, with an average thickness perhaps of 30. The continuation of this dyke is visible on each side, appearing like a narrow vein often not more than a foot wide, running from the Roche Rouge towards the N. W. and S. E. It may be

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possible effects to the decomposing, wasting, and abrasive influence of meteoric agents; not measuring their power by the scale of our limited observations, nor the duration of their action by the microscopic span of our own existence! The tendency of coarse conglomerates to waste into pyramidal forms is generally known. Its cause is disclosed in the striking instance of the "Pyramids of Botzen" in the Tyrol, each of which evidently owes its preservation to a large boulder which caps its apex; whence it follows that the amount of excavation produced in the conglomerate bed of which these and similar pyramidal remnants formed a part, was effected solely by the force of direct vertical rain.

traced to a distance of 500 or 600 yards; its course being rather sinuous than straight. The basalt is partly scoriform and cellular, partly divided into small columns laid perpendicularly to the walls of the vein. The granite of these is scarcely at all affected, and sometimes adheres firmly to the basalt.

The only question that can be raised on the mode of formation of this dyke is whether it was propelled from above or below; in other words, whether it is the remains of the chimney of a volcanic eruption, or a portion of basalt from a current above, which in the state of lava insinuated itself into a fissure pre-existing in the granite. And the probabilities in favour of one or other of these alternate hypotheses are pretty equally balanced.

In support of the latter, it may be observed, that the bed of basalt of which the Montagnes de Douc and Servissas are the principal remaining segments, certainly once extended over this spot, and that instances of such currents having pushed forth considerable dykes into the granite on which they rest, are, as we have seen, by no means uncommon; while those who prefer the opposite opinion may allege the freshness of aspect, both of the scoriæ and basalt of the Roche Rouge, and the frequency of recent volcanic eruptions in the neighbourhood, (to whose description we are now arriving,) each of which must in all probability have left some such dyke as this filling the fissure through which its lava ascended. For myself, I incline rather to the idea of its ascent from below; and that we have in it an example of the condition which every ordinary volcanic vent productive of but a single minor eruption of basaltic lava would exhibit, when stripped of the outward coverings of scoriæ and other fragments, that in almost all cases conceal the orifice in the superficial rocks through which these matters were protruded. There appeared to me to be a separate axis of basalt penetrating the heart of the Roche Rouge, as if the lava had continued to be expelled through a central channel, after the external parts which were in contact with the granite had been consolidated to a considerable depth.

§ 3. *The Products of more recent and scattered Eruptions.*

We now come to the volcanic remains of the second class occurring within the departments Haute Loire and Ardêche. These are the products of a later epoch of volcanic activity, and almost uninterruptedly cover a broad

zone of the primitive plateau from Paulhaguet and Alègre to Pradelle and Aubenas. They appear to constitute the prolongation of the Chain of Puys of the Auvergne.

The various points on which these eruptions have broke forth are still marked by numerous volcanic cones, whose formation, as in Auvergne, accompanied the development of the volcanic phænomena. They are so thickly sown along the axis of the granitic range that separates the Loire and Allier from Paulhaguet to Pradelle, as generally to touch each other by their bases, and form an almost continuous chain.

On both sides of this they are more sparingly distributed, dotting here and there the slope towards either river; a few being also found on the further side of each. Between Pradelle and Aubenas they occur more rarely; and none to the south of the latter town. There is, however, a large and productive group to the N. E. of Pradelles in the vicinity of Prezailles. Throughout the above-mentioned tract I counted more than a *hundred and fifty* of these cones, and probably omitted many.

They are by no means in the same state of freshness and preservation as the great proportion of those we have noticed in Auvergne. Not many present an entire, or even a distinctly marked crater, and the generality have wasted to ridgy saddle-shaped hills, a form which volcanic cones have frequently been observed to assume by degradation. As usual, they are solely composed of slaggy and funiform scoriæ, lava-bombs, lapillo, volcanic sand, fragments of granite and basalt, and sometimes massive portions of this last rock *in situ*, the relics of the currents which descended their flanks, or boiled up within their craters from the vent beneath. Their surfaces are scantily clothed with a meagre herbage, and occasionally a few stunted Scotch firs; but their dilapidation is incessantly going forward by means of frequent and shifting rents.

The lava currents, whose emission accompanied the formation of the cones of the principal chain, must have been exceedingly abundant. According to the position of the point of eruption, with respect to the slopes of the granite range, they appear to have directed themselves either to the east or west, descending into the bed of the Loire on one side, and of the Allier on the other. The former have covered nearly the whole eastern slope of the range, (the granite which forms its nucleus appearing only at distant intervals or in ravines worn through the basaltic beds,) and are continued over the freshwater strata in a uniform sheet forming a very extensive and but slightly inclined tract, which they seem to have completely deluged.

There is every indication that, by these prodigious and perhaps nearly simultaneous irruptions of lava upon the basin of the Loire, the river was driven from its former bed, and forced back upon the slope formed by the similar products of the Mont Mezen. It probably long erred between the two, every fresh invasion partially shifting, and raising the level of its channel, so that its actual valley is excavated as well through the vast mass of basalt and breccia, which we have seen proceeded from the habitual vent of the Mezen, as through an uppermost bed, generally single, of basalt alone, which in its fresher aspect, and uniform inclination from the chain of volcanic cones, is proved to derive from them. These later lavas are separated usually from one another, when repeated, and also from the older basalts and breccias, by beds of conglomerate containing scoriæ, fragments of granite, &c., and often layers of bouldered pebbles, showing the currents to have occupied, as usual, the shifting beds of the rivers and mountain torrents. Where the fragmentary matter has been taken up and deposited by these torrents, breccias have been produced identical with those of an earlier epoch.

These changes in the position of the Loire seem to have been accompanied by the progressive excavation of that deep and narrow gulley through which this river now escapes from the basin of the freshwater formation of Le Puy*, and which could not have existed at the period of the flowing of certain beds of basalt (the plateaux of Chambeyrac and l'Oulette) that are seen capping its perpendicular banks; or, if it existed, must have been completely choked up to the level of these plateaux, like the valleys of the Bas Vivarais, which we shall shortly have to notice. This channel has been worn irregularly across the high granitic embranchment of Chaspinhac which separates the basin of Le Puy from that of Emblavès (a minor division of the same freshwater formation), and may perhaps have been partly occasioned by the creation of a fissure in that direction by some of the earthquakes attendant on the volcanic eruptions. It is even probable that the waters of the lake were previously discharged by some other outlet, perhaps over the low part of the granite ridge between Blaves and St. Etienne.

After traversing the lower basin of Emblavès the Loire finally issues through another defile, where its passage seems once to have been effectually barred by the great current of clinkstone already described, of which two colossal remnants, the rocks Miaune and Gerbison, rising on either

* See Plate XII.

side the gorge to a height of 1800 feet above the river, attest the original elevation. That this enormous dyke suddenly thrown across the valley of the Loire must have caused its waters to accumulate into a lake covering the whole extent of the freshwater formation, is extremely probable. It is not however to this event we can attribute the original creation of the lake in which the freshwater strata were deposited; for the granite which supports the bases both of Gerbison and Miaune at a height of 1100 feet above the present river, would alone have formed a sufficient barrier for that purpose; and we have also seen that there is reason to conclude the clinkstone more recent than the freshwater formation.

The gradual erosion then of the gorge of Chamalière, through both the mass of clinkstone and the granite on which it rested, was probably coeval with that of the channel of discharge of the upper basin; and some remnants of basalt which show themselves attached to the sides of the excavation at Pierre-neyre and Artias, prove the former to have been occupied at intervals during this process by lava-currents from the neighbouring vents of eruption.

Among the Puys of the Monts Dome we are enabled by their comparatively rare occurrence, and the intervals of primitive soil which separate their products, to trace almost every stream of lava to the crater which marks the spot of its emission; but in this chain of vents the cones are more numerous and closer, the volcanic energy seems to have been exerted far more furiously, and the lava-currents to have united into one continuous and enormous crust, where all are mingled and confounded*. An

* A most striking similarity exists between this chain of volcanic cones, and that in the island of Lancerote, one of the Canary Isles, which was the result of the tremendous volcanic effervescence that island was subjected to between the years 1730 and 1736. Within the space of these six years successive eruptions produced upwards of 30 cones, arranged nearly on one line running E. and W. across the whole island, (evidently indicating a great subterranean fissure, from different points of which the ebullient matter forced its way up wherever it found least resistance,) and a sea of basaltic lava covering many square miles of surface. A very interesting description of these volcanic products, accompanied by a relation of the principal occurrences of the eruption from a MS. narrative, written by an eye-witness, has been published by M. de Buch. The formation of so many distinct cones on a fissure of this length, within so short a space of time, leads to the supposition that many of the eruptions which threw up the Puys of Auvergne and the Velay were similarly circumstanced. Not that the whole chain was contemporaneously produced, for this is opposed to the numerous appearances of unequal antiquity already dwelt upon at length in their description, particularly with respect to those of the Monts Dome; but that epochs of intense activity alternating, as is the usual

extensive and gently sloping plain has thus been created, appearing thinly dotted by the cones which have been thrown up to the west of the principal line. Each of these has in all probability furnished its contingent to the sea of basalt that overspreads the plain; but all attempt at appropriation is out of the question. A few show themselves in the vicinity of Le Puy, above the great volcanic bed, which descending from the Mezen, had previously invaded the basin of the freshwater formation. Such are the Montagnes de Danis, Seinzelles, Crousteix, Eysenac, and Mont. In their scoriæ are implanted numerous fragments of granite and gneiss: these suffice to prove that the focus of their eruptions was more deeply seated than the subjacent breccias and basalts through which they burst. To one of these eruptions, and probably to that which produced the double hill of Mont, S. E. of Le Puy, is owing a small platform of columnar basalt called Montredon, rising in the middle of the valley of the Borne, and resting on a shingle of primitive and volcanic boulders, evidently at one time the bed of the river, though now more than 50 feet above its present channel. This seems to have been one of the most recent eruptions of the district.

In other instances, as near Chaspinhac, St. Geneys, Couron, Alègre, &c., the cones rise immediately from granite. That in the neighbourhood of the last town called *La Montagne de Bar,* has a large and regular crater at its summit, about a mile in circumference and 150 feet in depth. A flat area 700 feet in diameter occurs at the bottom, which once contained a small lake or pool of water, but has been artificially drained by a channel cut through the lowest part of the incircling ridge.

The lava-streams which descended from the principal range of cones towards the Allier, have in a similar manner incrusted the western slope with a thick coating of basalt, and appear to have occupied the bed of the river nearly in its whole extent from Langogne to Vielle Brioude. The primitive chain of La Margèride, however, rising immediately from the western banks of the Allier, drove the river back upon the masses of basalt that had usurped its channel, and through these it has been constrained to excavate a fresh one. By this process have been disclosed many most magnificent mural ranges of columnar basalt which at St. Ilpize, Chiliac, St. Arçon, Monistrol, &c., incase and frown over the river. They are often

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character of volcanic action, with lengthened periods of quiescence, frequently gave birth to a great many eruptions from independent vents within a short space of time, creating as many distinct cones, arranged either in lines or groups, and as many streams of lava.

uninterruptedly connected with the volcanic cones on the slope or the summit of the range above.

The basalt originating in this linear group of volcanic mouths assumes on different points a very regularly columnar, a tabular, and a spheroidal concretionary structure. It sometimes also separates so readily and to such a degree into small angular globules from the size of a nut to that of a millet-seed, that the roads are strewed with them to the depth of some inches, and the foot often sinks into rocks of this nature as into a heap of gravel. In mineralogical characters the basalt varies from distance to distance. Among the remarkable kinds, I noticed one with very large spherical cells and an exceedingly crystalline texture; the interlaced grains being felspar, augite, and a bright yellow transparent olivine. It occurs round La Roche on the road from Le Puy to St. Privat; another, near St. George d'Aurat, dense, heavy, and iron-shot, contained still larger oblong cavities frequently coated internally with fiorite.

In this range also, as amongst the Puys of the Monts Dome, we meet with a few lakes occupying wide, deep, and nearly circular basins, which bear every appearance of having resulted from some violent volcanic explosions, but differ from ordinary craters, not only in their greater dimensions, but in the nature also and disposition of their inclosure, which is usually of primitive rocks merely sprinkled more or less copiously with scoriæ and puzzolana, and little if at all elevated above the surface of the environing country. Such are the lakes du Bouchet, de Limandre, d'Issarles, de St. Front, as well as a large and remarkable hollow, now drained, in which the river Fontaulier takes its rise, and which is traversed by the road from Usclades to Montpèzat. The latter crater contains a small parasitic cone rising from its bottom. I need not repeat here the remarks upon the peculiar modification of the volcanic phænomena to which this variety of crater apparently owes its formation, which were sufficiently dwelt on in the description of the Gour de Tazana*.

Between Pradelle and Aubenas the cones diminish in number, rising here and there through the great forest of Bauzon, and showing themselves up to the escarpment of the elevated platform of the Haut Vivarais.

But the most remarkable and interesting of the recent volcanic remains

* See also a Memoir on the Eiffel Volcanos, in the Edinburgh Journal of Science for June, 1826: and Considerations on Volcanos, p. 165.

of the line we are now considering, and perhaps of all France, are those that occur on the steep declivity by which this escarpment is connected with the great southern valley or Low-lands of the Bas Vivarais and Languedoc.

I have already described the primitive table-land as abruptly cut down on this side. Its rapid slope is intersected by deep mountain gorges, into which frequently open the transverse trough-shaped valleys of the coal formation. Viewed from below, this front of the great platform appears as a precipitous curtain-like range, broken by recesses into short, steep, and massive promontories, in which all the rude and stupendous scenery of a primitive mountain district is displayed in its full magnificence*. It is therefore an unexpected and striking contrast that is presented by a few single and regular volcanic cones perched at distant intervals upon the rocky ridges of these granitic embranchments; nor is it less surprising to find the gorges that sever them almost choked up to some distance by enormous flat-topped beds of columnar basalt, such as we have been accustomed only to observe as the cappings of elevated hills.

These remarkable characters belong to six different points of eruption, designated by the six very perfect volcanic cones of Montpèzat, Burzet, Thueyts, Jaujac, Souillols, and Ayzac.

1. The first, called by the peasants *La Gravenne de Montpèzat*, from the puzzolana or "gravier" of which it chiefly consists, is a cone of very large size formed on a granitic ridge which separates the rivers Fontaulier and Ardêche. It has a very regular bowl-shaped crater, gently inclined to the N.; in this direction the lava poured over its lowest lip into the basin of Montpèzat, which it entirely filled to an average depth perhaps of 130 feet, and a width of nearly half a mile. Hence it descends the valley to the confluence of the Fontaulier and Burzet, where it appears either to have stopped, the volcano having exhausted its efforts, or to have mingled with a similar current which reached the same point from above the village of

* It would be perhaps difficult to find in any range of mountains, scenes which present a more exquisite combination of beauty and magnificence than some of the valleys of the Bas Vivarais, so little visited by hunters of the picturesque. The rich glow of their chesnut forests, tinted by a soft and brilliant atmosphere, is far more adapted to painting than the cold transparent colouring of the Alps and Pyrenees, their pine-forests and waterfalls; nor can the outline of their masses be considered as much inferior in grandeur. The scenery is in fact that of the Apennines, but with a more luxuriant vegetation than that great *limestone* range can support.

Burzet. The mass of basalt thus deposited has been cut through in more than one direction by the powerful action of the rivers whose channels it usurped; its present disposition and the beautiful columnar ranges discovered by this excavation, may be imperfectly judged of from the annexed sketch taken near the junction of the torrents Fontaulier and Pourseille, about a mile below Montpèzat*. Similar ranges extend all the way to its termination at Aulière, where they are still more symmetrical, many columns being straight, vertical, and entire from top to bottom of the escarpment. The engraving published by Faujas, if its wretched execution be allowed for, will give a tolerably correct idea of the architectural regularity of this façade. The basalt may be observed on many points to rest on granite, with the intervention of a stratum of rolled pebbles. Its uppermost surface is bristled with rocky and scoriform projections, which, however, by decomposition resolve themselves into a rich soil affording nourishment to very productive chesnut forests.

Some way above Montpèzat, and just below the verge of the high primitive platform, is another cone of puzzolana and scoriæ, also seen in the engraving, which does not appear to have given birth to any lava-stream.

2. The bed of basalt which occupies the bottom of the valley of Burzet, and follows all its windings as far as the point where it opens into the Ardêche, a distance of 8 miles, proceeded from a point of eruption considerably above the village of Burzet, and at about the same elevation as the last-mentioned cone. It is chiefly remarkable for imbedding numerous nodular masses of olivine of a brilliant light green, and often as large as the fist. It is also very regularly columnar, and I observed it has not unfrequently happened that the seam separating two proximate columns cuts through one of the large imbedded knots of olivine, leaving a segment on either side. This fact proves most conclusively two points with respect to the columnar divisionary structure: viz. 1st. That it is attended by a *most powerful contractile force*. 2dly. That it does not take place till the lava is entirely consolidated, and the knots of olivine consequently so firmly compacted in its crystalline substance, as to separate along the line of the seam even when it divides them in two, sooner than quit their matrix†.

* See Plate XV.

† In the face of such a fact as this, it is impossible to deny the reality of the *contraction*, or to talk any longer of the columnar structure being occasioned by the "mutual *pressure* of spherical concretions."—See Scrope on Volcanos, p. 135 et seq.

In its disposition, or more properly speaking, its aspect, this bed differs from that last described; for the river instead of cutting a deep channel through the mass, and consequently exhibiting vertical sections of it on either side, generally flows over its surface, the upper and amorphous part of which it has worn away, and thus disclosed on many points a plane horizontal section, in which the polygonal extremities of the columns are united into a sort of pavement, (called by the natives *pavés de Géans*, or Giants' causeway,) not unlike those of the Roman roads in Italy, but arranged with far greater neatness and accuracy of design.

The columns here, as throughout the Bas Vivarais, are usually hexahedral, often of five sides; those of four occur rarely, of seven still seldomer; I have never seen any of eight or nine; and of three, only when interposed between larger columns in the manner of a pyramidal wedge.

The columns are habitually of small diameter, not often exceeding ten or at most twelve inches. They are sometimes divided by very frequent joints; at others attain a length of 60 feet without any separation.

It struck me as a remarkable, and perhaps not a fortuitous coincidence, that while the basaltic lava of Burzet is thickly sprinkled with knots of olivine, the granite, from the interior of which it has flowed in such abundance, contains an equal proportion of similarly shaped and sized nodules, composed of granular pinite with interspersed mica and quartz; this character prevailing only in a certain district near the site of the eruption. If the basaltic lava was derived from the fusion and recrystallization of granite, the knots of pinite may perhaps have been converted during the process into olivine?

3. The volcanic cone to the east of the village of Thueyts is connected with that of Montpèzat by a small portion of the primitive ridge on which both eruptions broke forth, probably at the same epoch. It is much inferior in size to the other, and without a regular crater; but has vomited an abundant flood of lava into the bed of the Ardêche. Thueyts is built upon its surface, which is cellular, and scoriaceous. The river has gnawed out a new channel between the bounding cliffs of this plateau and the granite of its southern bank, and exhibited a majestic colonnade of basalt, about one hundred and fifty feet in height, and extending with few breaks for a mile and a half along the valley.

4. The cone of Jaujac *, called *La Coupe de Jaujac*, from its cup-

* See Plate XIV.

shaped crater, has this peculiarity, that it rises from a coal formation, occupying the bottom of a long transverse valley, between elevated ranges of granite and gneiss, and would thus appear to countenance the exploded notion that volcanic fires are alimented by immense beds of coal. The primitive fragments, however, frequently found enveloped by its scoriæ and basalt, sufficiently prove, if proof were wanting, that the source of the erupted matters existed, at least, below the sandstone which incloses the coal strata.

The crater is very large and regular, but breached towards the North. Its figure is elliptical; the longer axis being directed N. and S. Its sides as well as those of the cone are thickly clothed with chesnut-woods; and it is remarkable here as elsewhere, that those trees which grow on the volcanic are much larger and more productive than those on the primitive soil around. The earth resulting from the trituration and decomposition of recent basalt seems to be peculiarly favourable to the vegetation of the Spanish chesnut. Those of the woody region of Ætna are a well known instance of prodigious luxuriance. At the foot of the cone gushes a mineral spring strongly impregnated with carbonic acid gas.

From the northern breach of the crater may be traced a vast current of basalt, which occupies and descends the valley of the Alignon to a distance of between two and three miles. The village of Jaujac stands upon this bed, on the brink of a mural precipice, which is continued to the termination of the current, and everywhere presents a columnar range of almost unexampled beauty, about 150 feet in height.

The river has excavated its channel between this and the granite of its western bank, but on the other side the bed of basalt, which is of considerable width, is closely soldered to the opposite range of primitive rocks, whose debris accumulating at their base into a cultivated slope have concealed the line of junction. The lava of the Coupe de Jaujac either stopped without reaching the Ardêche, or, which is more probable, is confounded with that of another neighbouring cone, called

5. *La Gravenne de Souillols,*

which also disgorged its lava into the bed of the Alignon about 300 yards above the junction of this river with the Ardêche. A wide and massive plateau of basalt thus formed, after entering the valley of La Baume, prolongs itself to some distance below Niaigles, bordering the Ardêche on the

south with a bold and precipitous wall which may be seen to rest on a layer of pebbles, the ancient bed of the river.

The face of this line of cliff, as well as that of the current of Jaujac, exhibits two distinct portions or stories separated by a well defined straight line generally parallel to both surfaces; the upper consists of small, irregular, and matted columns; the lower, habitually occupying about one third of the whole height, of large, perfect, and vertical pillars, which almost appear placed as an artificial support to the immense superincumbent entablature. On a close inspection the regular columns below are seen to proceed so immediately out of the upper and comparatively amorphous mass, that it is evident the whole was cast at once, and the two portions cannot be considered as different beds or currents *. Their singular difference of structure may be accounted for, I conceive, by supposing the elastic vapour contained in the lava to have escaped from the upper part through fissures of retreat formed in irregular directions as the mass cooled; while the immense pressure acting on the lower part would at the same time prevent the *escape* of the contained vapour, and effect its *condensation*, thereby allowing the mass to consolidate in a regular and tranquil manner, such as would facilitate the establishment of straight and vertical axes of contraction, and the production of very regular hexahedral columnar concretions †. A view of part of this range near the Pont de Baume engraved in the work of Faujas, after due deductions for exaggeration in size and its faulty execution, gives not an inaccurate idea of the disposition of the columns.

It is here that the river descending both from Burzet and Montpèzat joins the Ardêche; so that if we suppose their eruptions to have been contemporaneous, or nearly so, it is not at all improbable that the five lava currents we have described, flowing from as many different points, were once united on this spot exactly as the rivers were, and still are, whose channels they usurped. In the bed of the river Ardêche, at and for some distance below this point, may be seen in summer when the stream is inconsiderable, a number of articulations of basaltic columns, in which a nice observer may recognize the mineral characters of the different lava currents of the tributary valleys. As you follow the course of the river, these columns show themselves less frequently and are more water-worn, till at the distance of about a mile they are reduced to little more than rounded blocks, and nearly assimilated to the other boulders which cover

* See Plate XIV. † See Considerations on Volcanos, p. 136.

the dry channel of the river. These basaltic boulders continue to diminish in size as you descend, and few are to be met with as far down the stream as Aubenas, so large as a man's head; further on they are reduced to mere pebbles, and are no doubt still more comminuted before the Ardêche carries them with it into the Rhone. This observation illustrates the process by which both the basalt and granite that once filled these valleys have disappeared. A wintry flood undermines and detaches a prism of basalt from one of the columnar ranges. The next flood drives it on a few inches; or, if by its form and position it is enabled to roll without much difficulty onwards, a few feet. This operation is repeated year after year, and in the mean time, even when remaining stationary, it is exposed to the immense friction of all the smaller boulders and pebbles which are drifted over it by the ordinary as well as the extraordinary force of the current. By the continuance of this process it is at the same time carried forwards, reduced in size, and brought to approach to a globular form, the most favourable to its transport, in consequence of which the rapidity of its progress along the channel of the river is progressively accelerated, till, diminished to the size of gravel or silt, it is taken into complete suspension, and carried sooner or later in this state into the ocean.

At the foot of the cone of Soulliols, near the hamlet of Neyrac, rises a spring strongly impregnated, like that of Jaujac, with carbonic acid gas; and from the bottom of a small hollow close by, this gas emanates in such abundance that the exact phænomena of the Grotta del Cane are reproduced, and dogs or fowls may be stifled and revived *ad libitum*.

6. The last of the cones we have mentioned, called *La Coupe d'Ayzac*, rises on the ridge of one of the granitic abutments that project from the steep escarpment of the Haut Vivarais. It has a beautiful crater slightly broken down towards the N.W.; and from the breach a stream of basalt may be seen to descend the flank of the hill, and turning to the N. E. enter the valley of the river Volant; which has subsequently cut it entirely across, and disclosed three distinct storied ranges; the lowermost very regularly columnar, that in the middle less so, and the upper nearly amorphous, cellular, and with a ragged scoriform surface *. This current, which appears originally to have occupied the whole bottom of the gorge in an

* See the annexed drawing, Plate X. Faujas's view of this cone and its lava is so shamefully erroneous as to prove it to have been, to say the least, drawn or dictated from very imperfect recollections. The crater is completely out of sight from every spot whence any thing like his view could have been taken.

extent of about four miles, from the village of Antraigues nearly to that of Vals, where the Volant flows into the Ardêche, has been worn away and carried off on many points by the violence of the torrent. Its relics adhere in vast masses to the granite rocks on both sides, particularly in the receding angles of the valley, sometimes bordering the river for a considerable distance, and reaching the height of 160 feet above it. As usual, the lower portion of this bed is very beautifully columnar, the upper obscurely so; this latter has been in parts destroyed, and a pavement or causeway left, formed by an assemblage of upright and almost geometrically regular columns fitted together with the utmost symmetry; as in the mass near the Pont de Bridon engraved by Faujas.

Such are the volcanic remains of the Bas Vivarais; they evidently form the continuation of the line of recent eruptions which we have noticed on the lofty table-land above.

The exceeding freshness of their scoriæ and the general regularity of their craters would seem to indicate their being of a later date than the others; but this state of superior preservation may with greater plausibility be attributed to their minor elevation and more sheltered position; and the vast excavations already accomplished by the erosive force of the mountain streams along the valleys which feed the Ardêche, since their invasion by currents of basalt, undeniably prove the origin of these, however recent in comparison with the beds of the same nature around the Mezen, to belong to an æra incalculably remote with respect to ourselves.

There is one instance in the immediate vicinity of Aubenas, in which an imperfect or abortive volcanic eruption appears to have taken place within, but at little distance from, the limits of the secondary limestone formation. The hill upon which this town is built consists of strata dipping to the S. at an angle of 10°. Within a hundred yards N. of the town walls, and scarcely so much from the sandstone on which they rest, these limestone strata are abruptly broken through by an enormous vertical dyke of basalt, which protrudes about 30 feet above the summit of the hill, and may be traced down its side into the valley of the Ardêche, pursuing an easterly direction. At the lower part of the hill the dyke measures from 12 to 20 feet between its

cheeks; higher up it increases in bulk, and at the summit is 90 feet thick. From thence it makes a sudden curve to the N., returns to the N.E., and is again to be traced down the same face of the hill about a hundred yards from the other branch; thus including a large portion of the limestone strata, which preserve their parallelism and general inclination. This second branch of the dyke has dislocated and shattered the limestone within a space of from 40 to 50 yards, enveloping blocks and fragments of all sizes, with which it is mixed confusedly, and presents the appearance of a loose limestone breccia traversed or cemented by veins of basalt. Two smaller veins may also be observed cutting perpendicularly the undisturbed limestone strata inclosed by the two arms of the principal dyke. The one is 15, the other 10 inches thick.

The basalt itself is of a very dark gray colour, compact, fine-grained, hard, and tough; its fracture tends imperfectly to the conchoidal, and it breaks into curved and angular pieces. It incloses numerous large crystals of greenish black augite, and a brilliant sea-green olivine. It is almost universally penetrated by calcareous infiltrations, which line all the cavities of the cellular parts with snow-white calc-spar, and are even found in the interior of some of the crystals of augite. Small fragments also of limestone are enveloped by the basalt, to which they adhere firmly, the two substances appearing soldered together by an intimate though partial mixture. Occasionally the whole inclosed fragment of limestone is hardened, of a dark gray colour, a granular or crystalline texture, and a siliceous or cherty aspect; in some instances on the contrary, it is white, earthy, and effervesces readily with acids; while in others the basaltic and calcareous particles seem to have united and separated again, the latter into small grains or patches resembling white porcelain imbedded in a dark gray basaltic base. The large masses of limestone in contact with the veins exhibit few or no signs of alteration.

The whole appearance of this dyke and its subordinate ramifications announces its having been forcibly propelled from below through the calcareous strata; but at what epoch, or whether connected in any way with the neighbouring eruptions whose products have been described above, it is difficult even to conjecture.

This is the most southern instance of any volcanic formation which attaches itself to the primitive mountain-group of Central France. The interval from hence to the neighbourhood of Beziers, Agde, and Pèzenas, or

Aix and Toulon,—all points upon which volcanic remains are also to be found,—is, I believe, totally exempt from such substances; and it seems a very fair conclusion, that the enormous mass of secondary strata which from this spot southward covers the fundamental primitive formation, and consequently the focus of all volcanic energy, has stifled and impeded its ulterior development.

CHAPTER VII.

CONCLUDING REMARKS.

IF we now turn to take a wide and general view of the interesting tract whose particular formations have been described in the preceding pages, some of its most prominent features will be found to suggest considerations of no mean geological importance.

1. We first remark the peculiar disposition and bearings of the great mass of (so called) primitive rocks, piercing, like a vast protuberance, through the secondary strata which on the South and East abut at a steep angle against it, while on the North and West it sinks gradually beneath nearly horizontal strata, which continue the general and uniform slope of its surface from the high southern escarpment of the Monts Mezen and Lozère to the shores of the Atlantic, and the plains of northern France.

2. It is observable that no marine deposits later than the Jura limestone are to be found within the area of this elevated district, or nearer to it than the low chalk hills of Champagne and Touraine, on the North, and the still lower basin of Languedoc on the South; while in lieu of these a very massive calcareous, and in part arenaceous formation, the accumulated sediments of one or more extensive freshwater lakes, occupies the principal depressions in the primitive table-land, and prolongs itself from thence northwards as far as Nevers and Moulins.

Having noticed at least three of these calcareous freshwater deposits within the mountainous district to which our examination has been confined, the question naturally rises in the mind, whence could such immense accumulations of carbonate of lime be derived? Other examples of analogous formations are usually found in cavities surrounded by chalk or secondary limestone. M. Marcel de Serres even asserts this to be invariably the case. The calcareous formations of Auvergne, the Cantal, the Haute Loire, and Montbrison are entirely cased in granitic rocks. This circumstance wholly

prevents our supposing the carbonate of lime to proceed from the detritus of other limestone strata; and it is therefore to the calciferous springs of St. Alyre, Rambon, Chalucet, and the numerous others of a similar nature which we can hardly doubt to have existed when the subterranean forces of this district were in greater activity, that we can alone look for its origin. A large proportion of the lime emitted from such of these sources as were below the level of the lakes, was first probably secreted by the charæ and other aquatic plants growing from their bottom (of which numerous impressions are still found), and thence taken as food into the substance of innumerable testaceæ, which by their accumulation and gradual deposition gave rise to the marly strata of these lake-basins; while on those spots where the springs produced the matter in abundance, or in the open air, beds of more or less compact semi-crystalline limestone were formed by its precipitation. This view is strongly confirmed by the occurrence both of siliceous matter, which is known to be frequently deposited from thermal springs in a volcanic country, and also of gypsum: for it has been shown that eruptions were habitually taking place during the deposition of the calcareous strata of the Limagne, the Cantal, and probably also the Haute Loire: and if sulphuretted hydrogen was evolved, as is usual during these phænomena, through the soft marly beds at the bottom of the lakes, the sulphuric acid uniting with the lime would necessarily produce that mineral: of which a part may have been precipitated on the spot, and the remainder dissolved in the water and carried away into the lower lake-basins to be ultimately deposited there, (Gypsum of Paris?). The strong odour of sulphuretted hydrogen emitted from the marly limestone of Le Puy seems indeed to prove that this gas was produced at the epoch of its deposition.

In fact, the calcareous freshwater formations of the centre of France differ but in one respect (viz. the presence of silex, which the thermal volcanic springs will account for,) from the recent shell marl deposits of the Bakie and other lochs in Scotland, described in the admirable paper of Mr. Lyell in the Geological Transactions. In both are found Limnei, Planorbes, Helices, a species of Cypris, the remains of Charæ and the Gyrogonites. In both, marly strata in which all traces of shells have disappeared, but which occasionally contain bones of mammalia and birds, alternate with others of a yellowish tufaceous limestone, often semi-crystalline, tubular, containing remains of vegetables, insects, &c., and with beds of sand. The basins of both still contain springs charged with carbonate of lime, and both occur in the neighbourhood of trap or volcanic rocks.

3. With regard to the rocks of volcanic origin, they are distinguished primarily into, 1st. The products of three great habitual vents, the Monts Dor, Cantal and Mezen, which appear to have been in activity towards the same time, and to have raged at intervals and with intense energy during a period of considerable duration. 2ndly. The products of single occasional eruptions from a vast number of separate apertures, ranged closely along the line of what was probably a great fracture in the superficial granite, stretching from N.N.W. to S.S.E., across the whole elevated tract, coincident with the general direction of its beds, and therefore with the axis of elevation. Both classes of volcanic products exhibit a great variety of mineral composition, from coarse feldspathose trachyte to compact augitic basalt. Both rest indifferently upon the granitic rocks and the freshwater strata, and even in some instances are found to alternate with the latter, as for example the trachyte of the Cantal near Aurillac, and the basalt of Gergovia, Pont du Chateau, &c. The latter circumstance sufficiently proves eruptions to have taken place habitually from both the principal volcanos and the longitudinal fissure, during the period of the deposition of the freshwater formation. But it is equally certain that a large proportion of the basaltic lavas emitted from vents upon the Monts Dome were erupted subsequently to the emptying of the freshwater lake of the Limagne, since they have filled hollows and valleys eaten out of its stratified deposits.

The immense difference of level between some remnants of these calcareous deposits and the similar strata in the neighbourhood of Moulins and Nevers which appear to have been once continuous with them, has already led us to adopt the opinion that the former have been forcibly elevated since their deposition, together with the mass of underlying and neighbouring crystalline rocks which composes so large a portion of Central France: for that the individual hills, which remain to attest the great height attained by this formation, (the Puy d'Opme, Girou, Gergovia, Dallet, &c.) were not *separately* elevated, is certain from the absence of faults, flexures, or other traces of disturbance, and from the uniform and gradual declination of their basaltic cappings from the higher granite range, whence the lavas flowed. If this reasoning is allowed to be correct, it will appear probable that the same tremendous earthquake by which this elevation must have been accompanied, discharged the waters of the extensive Limagne lake; and the violent debacle thus occasioned may be supposed to have swept away whatever barriers existed across the valleys of the Loire and Allier, (damming up their waters into a chain of lakes which may have extended

from the Mezen to Paris,) and to have excavated also a certain proportion of the present vale of the Limagne.

The epoch characterized by this elevation and the accompanying debacle, was evidently succeeded by a period during which eruptions continued at intervals to take place from numerous points of the great longitudinal fracture in the granitic crust, which had been no doubt enlarged and extended during the process of elevation. This period occupied a very considerable time, since valleys of every degree of depth have been worn away by the slow influence of meteoric agency operating from its commencement up to the present time; while a few of the latest eruptions seem to have occurred so recently as to excite astonishment at the silence of all historical records on their subject. The former assertion, however, being opposed to the generally received opinions on the subject, it will be necessary to bring forward at some length the proofs upon which it rests.

That the bursting of the freshwater lakes may have opened up a great part, particularly the lower end or mouth of the valley of the Limagne, and traced the outline of the most marked of the present depressions in the surface of this district, may be safely conceded; but the great variety of levels at which the basaltic lava currents that have flowed from the Monts Dome into the basin of the Limagne are now found, proves, almost incontestibly, that the lowering of this principal valley and the excavation of its subsidiary embranchments were not suddenly but progressively executed, and by the agency of forces still in operation.

It is indeed impossible to observe the many strips of the originally continuous freshwater formation which rise from the plain of the Limagne in long tabular hills, without being convinced that they owe their preservation from the destruction which has swept away the remainder of the formation, to the capping of basalt which all alike possess, and which by reason of its superior hardness would naturally protect the underlying strata from the rains, frosts, and other meteoric agents, to which the uncovered intervals of the marly plain left by the emptying of the lake were permanently exposed. Such a capping, on the other hand, would afford a very inefficient protection against the denuding force of any violent deluge or general current of waters, to which some writers have attributed the excavation of the valleys intervening between these high basaltic platforms; more particularly as the direction of any such current passing over this district, must have been coincident with the general direction of the valley of the Limagne, or from South to North; whereas the long strips and flat

promontories in question *invariably* run East and West, preserving, as might be expected, the direction which was originally given by the lateral slopes of the valley-basin, to the streams of lava that flowed into it from the heights on either side.

Again, had the whole excavation effected in the freshwater formation of the Limagne been produced *at once*, by the debacle mentioned above, or by any *diluvial* or other violent catastrophe, it is clear that the remnants of the lava-currents which had flowed into the freshwater basin *before* this epoch, would be necessarily all found at one level, or nearly so, corresponding to the average level of the bottom of the lake-basin at that time; while on the other hand, all the lava-streams which have flowed since the debacle or supposed deluge, would be found at another nearly uniform, but much lower level, viz. that of the lowest places of the excavated valley. But, as we have seen, no marked distinction of this sort exists; no line can be drawn to separate the basaltic beds met with at high or low levels. They are found at all heights from 1500 to 15 feet above the water channels of the proximate valleys; and some even of the most distant in point of level are situated geographically close to one another.

Let us take, for instance, the two neighbouring basaltic platforms of Gergovia and La Serre, and the bed of basalt which occupies the bottom of the narrow valley that divides them, and which has flowed out of the recent vent marked by the Puy Noir*. Here are three long strips of basalt, each of which, by its gradual inclination in the direction of its greatest length, and by the positive remains of the cone of scoriæ in two instances out of the three, are proved to have flowed in a state of liquidity from volcanic vents opened upon the high granite platform, into the basin of the freshwater formation. Each must necessarily have occupied the lowest levels of that basin to which it had access; and therefore it is evident that at the period when the lava of Gergovia flowed into its present position, there could have been no lower depression in the immediate vicinity. The hollow, therefore, into which the lava of La Serre flowed, must have been subsequently excavated, as that bed is every where, that is, on every line drawn transversely across both plateaux, at a lower level by from 200 to 400 feet than that of Gergovia, which runs parallel to it, and not above a quarter of a mile distant. Again, by the same reasoning, it is evident that the intervening valley of Chanonat, the bottom of which is now covered by a still more recent bed of basalt, must have been excavated since the production of the lava of

* See Plate II. and also the Map of the Monts Dome.

La Serre, which overhangs it at a height of more than 500 feet. Here then are three distinct steps in the process of excavation, (it might be said *four*, for the rivulet of the valley of Chanonat has worn away a new channel, from 20 to 50 feet in some places below the substratum of the most recent of the three lava-currents,) while the diluvian theorists admit but of two, the *present* and the *former order of things*, or *state of our planet*, as they somewhat vaguely express themselves.

Every link in this chain of proofs is complete. In its mineralogical aspect the basalt of these different beds affords a confirmatory proof of their relative ages corresponding with their relative heights. That of Gergovia is compact, partly amygdaloidal, and much decomposed externally. That of La Serre has an appearance of much greater freshness, though still possessing the distinctive features of the older basalts. That of the inferior current of Chanonat is scarcely less recent in appearance than many currents of Ætna, of which the date is known.

Examples of this kind might be multiplied endlessly were it necessary, and with the foregoing reasoning lead inevitably to the conclusion, that the immense abstraction of matter which has occurred in the freshwater formation of the Limagne was for the most part effected *gradually* and *progressively*, and went hand in hand with the occasional flooding of parts of this valley and its tributary ravines by lavas emitted in the eruptive paroxysms of the volcanos on the neighbouring heights. Even were it allowable to have recourse to vague and hypothetical conjectures, we can conceive no *gradual and progressive excavating forces*, other than those which are still in operation wherever rains, frosts, floods, and atmospheric decomposition act upon the surface of the earth. To these agents then we must refer the effects in question, of which, with an unlimited allowance of *time*, no one will pronounce them to be incapable.

The ideal section of a part of the Limagne, seen in Plate XVIII, in which the most remarkable currents of basalt that have descended at different epochs into this basin are given at their respective heights, will show how completely these volcanic remains mark in their actual position the progressive steps of this excavation, and exhibit a natural scale for measuring the duration of the process; a scale to complete which nothing is wanting but a knowledge of the intervals which elapsed between the successive eruptions by which these lava-currents were poured forth from the ridge of the Monts Dome.

The lavas of the Bas Vivarais offer equally incontestible proofs of the

same fact. We see there a number of deep and narrow valleys worn in the flanks of a steep range of granite, which have at a certain epoch been occupied, through a length of several miles, by lava poured in a liquid state from neighbouring volcanic vents, which has evidently filled them up to a high level, exactly as melted metal fills a mould into which it is poured. Since that epoch the valleys have been re-excavated in many parts to more than their former depth and width, the new channel being cut in some cases through the basaltic lava, in others through the granitic sides of the original valley. Now if the first excavation of these valleys is to be accounted for by the hypothesis of a deluge,—to what are we to attribute the second process? Not, most certainly, to a *second deluge;* for the undisturbed condition of the volcanic cones, consisting of loose scoriæ and ashes, which actually let the foot sink ankle-deep in them, forbids the possibility of supposing any great wave or debacle to have swept over the country since the production of these cones. The amount of excavation which has taken place subsequently to the epoch of these eruptions *can* then have been only effected by the streams which still flow there; and as this quantity bears a very considerable proportion to the extent of the original excavation, there can be no reasonable grounds for hesitating to attribute the latter to the same agency which effected the former; it being only necessary to assign a longer duration to the process to account for the difference in magnitude of the result. Those who, having before their eyes the proof that the immense quantity of solid rock removed from these valleys since their occupation by the lava has been effected by natural causes, such as are still in operation, will yet recur to a vague and unexampled hypothesis for the purpose of explaining the removal of a similar, or not very much greater, quantity, prior to that epoch,—must do so in defiance of all the laws of analogical reasoning, by strict adherence to which we can alone hope to obtain the least acquaintance with those operations of Nature's laboratory of which we have not been actual eye-witnesses.

The volcanic district of the Haute Loire presents another chain of proofs equally conclusive of the same fact. It is impossible to doubt that the present valleys of the Loire, and all its tributary streams within the basin of Le Puy*, have been hollowed out since the flowing of the lava-currents, whose corresponding sections now fringe the opposite margins of these channels with columnar ranges of basalt, and which constitute the intervening plains. Yet these lavas are undeniably of contemporary origin with the

* See Plate XII.

cones of loose scoriæ which rise here and there from their surface, and which would necessarily have been hurried away by any general and violent rush of waters over this tract of country. It is indeed obviously impossible that any such flood should have occurred; and we are therefore driven to conclude, that the erosive force of the streams which still flow in these channels, together with the action of direct rains, frost, and other meteoric phænomena, have alone hollowed out this extensive system of deep, and in some instances (as that of the Loire itself) wide valleys*.

* It is scarcely necessary to attempt a serious refutation of a species of quibble which has been too often brought forward in place of argument by the diluvian theorists; viz. that rivers are caused by the pre-existence of the basins through which they flow, and consequently these could not have owed their existence to the rivers that flow through them! It is clear that no extensive surface of the earth could at any time have been so uniformly smooth and level but that the rains falling upon it must have collected into streams as they drained off. The erosive force of these streams would necessarily by degrees excavate channels of a depth and width proportioned to the duration of the process, their magnitude and velocity, and the more or less destructible nature of the rocks over which they flow.

In reality, it cannot be doubted that vast irregularities of level, elevations and depressions of the earth's surface, on every scale of magnitude, have been occasioned by other causes, chiefly subterranean expansion. The basins of our seas, lakes, and rivers, no doubt owe to circumstances of this nature their *primary* forms. Convulsive oscillations of the ocean, or other aqueous reservoirs, occasioned by the sudden heaving up of large masses of the earth's crust, *may* have subsequently sent repeated waves over parts of our continents, the effect of which would be to open communications between distant basins, to create new and extensive denudations, and accumulate vast beds of transported fragments along the course of these mighty currents. But the proofs of the passage of such destructive deluges over any country are *still to seek*. Those which have been adduced as yet have this inherent defect, that it is impossible, in the present state of our knowledge, to say that they cannot have been occasioned by the bursting of lake-basins, or other natural agents still in operation, acting during an unlimited period. Before any just estimate can be formed of what share must be attributed to extraordinary catastrophes, and what to these minor but constant excavating forces, of the whole amount of change which has been evidently produced by the action of water in motion on the surface of the globe, it is absolutely necessary to acquire a much more definite knowledge of the laws which regulate the circulation of water over the earth's surface, and its effect upon that surface, than we can at present be allowed to possess. It is too true that the greater number of geologists have sat down without hesitation to investigate by a sort of guess-work the origin of the changes and mode of production of the mineral masses which they observe on the surface of the globe, in complete ignorance, or at least with a total neglect, of those processes which are still daily employed by nature in the creation of fresh changes, and the production of new mineral masses on the same surface, bearing a complete analogy, to say the least of it, to the earlier phænomena, and older formations, which it is the business of geology to account for.

The time that must be allowed for the production of effects of this magnitude by causes evidently so slow in their operation, is indeed immense but surely it would be absurd to urge this as an argument against the adoption of an explanation so unavoidably forced upon us. The periods which to our narrow apprehension, and compared with our ephemeral existence, appear of incalculable duration, are in all probability but trifles in the calendar of Nature. It is Geology that, above all other sciences, makes us acquainted with this important, though humiliating fact. Every step we take in its pursuit forces us to make almost unlimited drafts upon antiquity. The leading idea which is present in all our researches, and which accompanies every fresh observation, the sound which to the ear of the student of Nature seems continually echoed from every part of her works, is—

Time!—Time!—Time *!

At least, since by a fortunate concurrence of phænomena we are enabled to prove the valleys which intersect the mountainous district of Central France to have been for the most part gradually excavated by the action of such natural causes as are still at work, surely it is incumbent on us to pause before we attribute similar excavations in other lofty tracts of country, in which, from the absence of recent volcanos, evidence of this nature is wanting, to the occurrence of unexampled and unattested catastrophes, of a purely hypothetical nature! More it is unnecessary to say at present on this subject.

To sum up the principal facts in the history of this district, as disclosed by its present appearances, may be briefly enumerated in the following chronological order.

1. The primary elevation of the high nucleus of Central France above

* It is very remarkable that while the words *Eternal*, *Eternity*, *Forever*, are constantly in our mouths, and applied without hesitation, we yet experience considerable difficulty in contemplating any definite term which bears a very large proportion to the brief cycles of our petty chronicles. There are many minds that would not for an instant doubt the God of Nature to have existed *from all Eternity*, and would yet reject as preposterous the idea of going back a million of years in the History of *His Works*. Yet what is a million, or a million million, of solar revolutions to an Eternity?

the ocean which deposited the secondary strata; by which a large protuberant mass of crystalline rocks, both massive and laminar, (granite, gneiss and mica-schist,) was erupted in a solid state and superficially exposed, the incumbent secondary strata apparently sliding away by a lateral movement on all sides towards the lower levels, a movement which was probably facilitated by the numerous beds of soft and slippery shales interspersed through them. The distant replications of these strata may perhaps be traced in the vertical and contorted limestones of the Pyrenees on one side, and of the departments of Isère, Drome, and Basses Alpes, forming the left bank of the Rhone, on the other *. Some patches of the lower series of secondary strata seem to have been entangled in the chief depressions of the elevated tract, and show themselves in the graywacke rocks of St. Sauve, the coal measures of Bassignac, Bourg Lastic, Brassac and St. Etienne, and the sandstones of Vic-le-Comte and Brives. There is nothing to show whether this elevation was effected at once by a single and tremendous effort of the force of subterraneous expansion, or by a series of successive convulsions with intervals of quiet between them. Analogy would lead us to conclude for the latter rather than the former of these alternatives.

2. After this occurred an æra marked by the abundant deposition of calcareous strata from a series of freshwater lakes, occupying the irregular hollows of the elevated district, and probably overflowing *en suite* the one into the other, from the highest to the lowest levels; while at the same time numerous eruptions of volcanic matter, both trachytes and basalts, were taking place at intervals from three principal habitual sources, as well as from some few minor vents opened upon a sort of crevice broken from N. to S. across the elevated district; in fact, along the axis of elevation.

3. This state of things seems to have been at length disturbed by a second paroxysmal elevation of the same immense continental tract, comprehending both the primitive platform and the overlying freshwater formations. By this the barriers of the lake-basins being burst, their contents were discharged upon the lower levels, in one or more sudden debacles, which produced extensive denudations throughout the valleys of the Allier and Loire by the force of the escaping waters, and perhaps deposited the vast accumulations of diluvial matter observable along the course of these rivers in the departments Allier, Nievre, and Cher.

* See Scrope on Volcanos, pp. 204, 211, et seq.

4. To this epoch succeeded a period of occasional volcanic eruptions, chiefly from separate openings on the longitudinal fracture-line; accompanied by the continual deepening and widening of the valleys of the district by ordinary excavating forces; a period which the apparent extinction of the volcanic vents cannot be said to have terminated, since some of these bear all the appearance of very recent activity, and render it by no means incredible that their phænomena may again be renewed at no distant date.

Changes of this magnitude in the superficial levels of the central parts of France could not occur without being shared, in a greater or less degree, by the remainder of the continent; and therefore, if the above inferences are correct, we ought to find in the geological features of the lower levels of France some appearances of sympathy in these disturbances, some corresponding traces, in particular, of the alternating periods of marked development and quiescence in the general subterranean force of elevation, which have been observed in the district more immediately subjected to its action.

Now when a great tract of country has been forcibly heaved up by the intumescence of subterranean lava, it follows naturally that, should any cleft have been created of sufficient depth and width to permit the extravasation of a large part of this compressed and ebullient matter, not only will all further elevation be for the time obviated, but a certain degree of *subsidence* may be expected to occur in the elevated parts as the lava escapes. In the high land of Central France, we have, as has been shown at length in the description of its geology, proofs both of the occurrence of a vast amount of elevation, at, certainly more than one, distinct epoch, and also of repeated and most abundant volcanic extravasations. Is it not then probable that these different modes of development of the subterranean force of expansion alternated, as is usual *, with each other; and will not this, together with the foregoing considerations, afford a clue to the origin of that remarkable alternation of freshwater and marine sediments which is found not only in the Paris basin, but in those of the Isle of Wight, the south of France, and elsewhere? May we not suppose that these distant levels having been raised but a little above the sea at the first elevatory epoch, were covered by the diluvial streams that flooded them, with the clays, sands, and lignites of the *plastic clay formation*;—that at this period the eruption of the first volcanos of Central France occasioned them to sink again be-

* See Scrope on Volcanos, p. 197.

neath the sea, there to be coated by the *calcaire grossier*;—that at length a fresh elevatory shock raising the boundaries of the basins once more into open air, they received the deposits of the waters flowing through a chain of lakes from the volcanic district of Central France, and charged with silex, carbonate, and sulphate of lime (*the siliceous and gypseous strata of Paris*);—that the continued extravasation of the subterranean lava by the vents of Auvergne and the Velay produced a second gradual subsidence, by which these strata were once more depressed below the sea level, to be coated with the *upper marine* formation, whence they again emerged by means of another elevatory expansion, (perhaps that final one to which we have been obliged to ascribe the high position of the Auvergne freshwater strata,) continuing in this situation to receive the calcareous precipitations and sediments of the streams which flowed from the central heights (*upper freshwater* formation)?

I am aware that partial admixtures, and even repeated alternations, on a very small scale, of marine and fluviatile deposits occur in the Paris and other basins. These, however, may be reasonably accounted for by minor causes; such, for instance, as the continual shifting of the mouths of rivers opening into a saltwater basin; for alternations of this kind must be no doubt produced even at present in the alluvial deltas at the mouth of the Po, Nile, Ganges, and other delta-forming rivers. But the large scale on which the three principal freshwater and marine tertiary formations have been produced, and their complete correspondence, not only on distant points of the same basin, but likewise in different basins, would seem to require causes of greater magnitude and of a more general nature. It is difficult to imagine any cause which should alternately admit the sea during one period to these basins and exclude it at another, but a succession of alternate elevations and subsidences affecting a considerable extent of the stratified crust around them. The occurrence of successive elevations are, it has been seen, to be traced in the centre of France; and it has also been shown, that we may with great plausibility suppose these to have been followed by depressions contemporaneous with the principal æras of volcanic eruption from these heights,—in other words, of the abundant escape of that heated matter whose intumescence was the cause of the several elevations of the overlying crust.

This explanation of the alternate deposition of marine and freshwater sediments in tertiary basins is submitted rather as a possible mode of accounting for a problematical fact, than as its only and complete solution. It

is by no means certain that partial subsidences of the remote levels do actually accompany the copious eruption of volcanic matter. All that can be said is, that it appears probable such an effect may be produced. The superficial levels *immediately* in the vicinity of the volcanic vents are, we know, on the contrary, rather elevated than depressed by the minor earthquake shocks that accompany the phænomena of eruptions. But this very circumstance would lead to the presumption, that at a greater or less distance depressions must take place in the prolongation of the same continuous stratum or crust, owing to, 1st, the increase of pressure on those points, occasioned by its angular elevation; and 2ndly, the diminution of the resistance opposed from below to this pressure, by reason of the continued escape of the intumescent matter through the vents of eruption, and the lateral movement this must produce in the general subterranean reservoir, from all sides towards the point of escape.

TABLE OF HEIGHTS

IN THE

VOLCANIC DISTRICT OF CENTRAL FRANCE.

[N.B. The greater number of these Heights are extracted from Ramond's *Nivellement Barometrique des Monts Dor et Dome ;*—the remainder are derived from articles in the *Journal des Mines*, by M. Cordier, &c., and from the work of M. Bertrand Roux.]

			Eng. feet above the sea.
Puy de Sancy, Monts Dor	Trachyte	*Ramond.*	6217
Plomb du Cantal	Clinkstone	*id.*	6096
Le Mezen, Haute Loire	Clinkstone	*Cordier.*	5820
Col de Cabre, Cantal	Clinkstone	*id.*	5545
Le Mont Lozère	Mica-slate	*id.*	5535
Le Puy Mari, Cantal	Clinkstone	*id.*	5446
Pierre-sur-Haute, Forèz	Granite	*Ramond.*	5400
Le Puy Violan, Cantal	Clinkstone	*id.*	5229
Puy de Dome	Trachyte	*id.*	4842
Source of the Loire, Haute Loire	Clinkstone	*B.Roux.*	4593
Estables, village, Haute Loire	Granite	*id.*	4436
Road from Le Puy to Pradelles, Haute Loire	Basalt on granite	*id.*	4203
Puy de Laschamp, Monts Dome	Scoriæ	*Ramond.*	4196
Petit Puy de Dome, Monts Dome	Scoriæ	*id.*	4187
Puy de Côme, Monts Dome	Scoriæ	*id.*	4173
Puy de Pariou, Monts Dome	Scoriæ	*id.*	4012
Puy de Cliersou, Monts Dome	Trachyte	*id.*	3992
Puy du Petit Suchet, Monts Dome	Scoriæ	*id.*	3983
Puy de Louchadière, Monts Dome	Scoriæ	*id.*	3956
Puy de Las Solas, Monts Dome	Scoriæ	*id.*	3950
Lac Paven, Monts Dor	Basalt	*id.*	3943
Puy de Mont-chat, Monts Dome	Scoriæ	*id.*	3933
Puy de Chopine, Monts Dome	Trachyte	*id.*	3910
Puy de Jume, Monts Dome	Scoriæ	*id.*	3848
Pey-Veuy, Haute Loire, near Montbonnet	Scoriæ	*B.Roux.*	3822

			Eng. feet above the sea.
Montagne de Bar, Haute Loire	Scoriæ	*B. Roux.*	3816
Grand Sarcoui, Monts Dome	Trachyte	*Ramond.*	3799
Puy des Goules, Monts Dome	Scoriæ	*id.*	3796
Puy des Montgy, Monts Dome	Scoriæ	*id.*	3792
Tête de la Serre, Monts Dome	Basalt on granite . .	*id.*	3461
Puy de Chatrat, Monts Dome	Basalt on granite . .	*id.*	3372
Puy de Manson, Monts Dome	Basalt on granite . .	*id.*	3310
Puy de St. Sandoux, Monts Dome . . .	Basalt on granite . .	*id.*	2821
Puy Girou, Monts Dome	Basalt on freshwater marly limestone .	*id.*	2792
Orcines, village, Monts Dome	Granite	*id.*	2779
Gravenère, Monts Dome	Scoriæ	*id.*	2723
Prudelles, Monts Dome	Basalt on granite . .	*id.*	2313
Côtes de Clermont, Monts Dome . .	Basalt on freshwater marly limestone .	*id.*	2089
Puy de Dallet, near Pont du Chateau .	Basalt on freshwater marly limestone .	*id.*	2007
Puy de Crouel, Limagne	Calc. peperino . . .	*id.*	1430
Clermont, Place de Jaude, Puy de Dome		*id.*	1286
Level of the Allier at Pont du Chateau		*id.*	1026

EXPLANATION

OF THE

MAPS AND ENGRAVINGS

ILLUSTRATIVE OF THIS MEMOIR.

MAPS.

No. 1.—"*The Volcanic District of Central France.*"

Comprising the greater part of the primitive Platform, and containing the departments *Puy de Dome*, *Loire*, *Rhone*, *Haute Loire*, *Cantal*, and parts of the *Ardèche*, *Lozère*, *Aveyron*, *Corrèze*, *Creuse*, and *Allier*. The areas occupied by the Volcanic products of the 1st and 2nd class are distinguished in colours, as well as those of the (so called) primitive, and tertiary or freshwater formations.

No. 2.—"*The Monts Dome and Part of the Limagne.*"

Exhibiting the Chain of Puys rising from the granitic platform which separates the Allier and Sioule. The extent of surface covered by the volcanic cones and their lava-currents is indicated by colours, as well as the limits of the primitive and freshwater formations, and the more ancient basaltic currents which have flowed from the Mont Dor in that direction.——N.B. Nos. 29 and 30, The Mont Chalar and the Gour de Tazana, the most northern points of eruption on this line, are not included in the map.

PLATE I.

Section presented by a line of Cliff on the banks of the Allier, a mile above Pont du Chateau, in which strata of limestone interspersed with volcanic fragments alternate with others containing freshwater shells. Behind rises the Puy *Dallet*, or *de Mur*, a hill consisting of horizontal strata of freshwater marly limestone alternating with compact beds containing the *Indusia tubulata*, and capped by a plateau of basalt. (See page 20.)

PLATE II.

Panoramic View of the Environs of Clermont, taken from the Summit of the Puy Girou, a conical peak of columnar basalt about four miles south of that town. The Chain of Puys of the Monts Dome is seen to the West, with the Puy de Dome in the centre, rising from the surface of the granitic platform. To the North lies the basin of Clermont eaten out of the freshwater formation, and overlooked by the primitive escarpment, on the edge of which rises the recent volcanic cone of Graveneire. Beyond Clermont are seen the basaltic platforms of Les Côtes and Chanturgues; in front a basaltic peak crowned by the Castle of Montrognon. Eastwards and above the village of Opme rise the Puy de Jussat and the plateau of Gergovia, both in all probability once continuous with the basalt of Girou. To the South is seen in its whole extent the basaltic platform of La Serre, partly resting on granite, partly on the freshwater marls, and terminating at the village of Le Crest. Beyond it rise the trachytic heights of the Mont Dor, and its basaltic embranchments; with the insulated basaltic heights of the Puys St. Sandoux, St. Saturnin, Coran, Monton, &c.

The horizon is closed by the mountains of the department of the Haute Loire. Immediately below these distant heights the valley of the Allier appears narrowed by the quantity of basalt which has flowed in that direction from the vicinity of the Mont Dor. Beyond the river rise an insulated group of hills capped by basalt and chiefly composed of freshwater limestone, but partly of granite and secondary sandstone. They are called the Puys de Millefleur, Mauriac, Dallet, &c. At the foot of this range flows the Allier, and immediately enters the wider expanse of the Limagne d'Auvergne, which bounded only eastwards by the distant granite range of the Forèz, stretches to the horizon on the North-east of the station. The cone of Graveneire, and the lava-current bursting from its side and spreading thence over a large surface of the lower plain, are remarkable objects to the north of the spectator.

This panoramic sketch, as well as the three next plates, and the panorama of the environs of Le Puy (Plate XII.), with one or two smaller drawings, are coloured geologically, but subdued tints have been made use of not very unlike those which the different rocks naturally assume, and thus the general effect is not materially injured, while the different formations can be distinguished at a glance.

PLATE III.

Distant View of the Chain of Puys, or Monts Dome, taken from a remnant of basalt crowning the western bank of the Sioule a short distance below Pont Gibaud. Nearly all the cones are visible; the most conspicuous are those of Louchadière and Côme. The lava-streams poured forth by these two vents may be seen spreading in broad sheets from the base of the cones over a wide extent of the granitic platform, and uniting immediately above the Castle of Pont-Gibaud to pour over the banks of the valley of the Sioule in a spreading sheet, which is, however, partly hidden by forest and underwood. That part of the lava-current which occupies the former bed of the Sioule is on the contrary still bare and rugged, its surface appearing like a series of heaps of loose basaltic blocks. Between this and the granite cliffs to the right, the river Sioule dashes and foams through the narrow channel it has excavated by undermining the granite. At the angle immediately beneath the spectator the basalt exhibits a regularly columnar structure.

In the distance to the right are seen the central trachytic eminences and plateaux of the Mont Dor, from amongst which the Sioule takes its rise.

PLATE IV.

Transversal View of the Northern Chain of Puys, from the Summit of the Puy Chopine. The cone of La Goutte which half incircles the Puy Chopine forms the foreground. The Puy de Côme and the commencement of its lava-current are seen to the extreme right. The Puys de Dome, Clierzou, Suchets, Pariou, with the beginning of its lava-stream, &c., in the front; and the group of Les Goules and the Sarcouis with the Puy Chaumont, on the left. The Mont Dor and the Mountains of the Forèz and Haute Loire skirt the horizon, to the right and left. The observer looks due south.

In this Plate as well as in the two following ones the hills consisting of trachyte are coloured blue, those of scoriæ red, the basaltic lava dark gray, and granite yellow, as in Plate II. and the two following plates.

PLATE V.

Lateral View of the Northern Chain of Puys from the East, taken between Volvic and Channat. The cone and crater of Nugère are observable on the right; a current of lava appears still to boil over on two of its sides; after incircling a knoll of granite it enters the valley of Volvic, which it threads in its course towards the plain of the Limagne. Immediately to the left of the Puy Nugère is the wooded group of cones called the Puys de Jumes, la Coquille, and Leironne; from the foot of which a sheet of lava overspreads the surface of the granite platform, and

entering a narrow gorge between the point of view and the Puy Channat on the left, finds its way into the low plain of the Limagne which it has flooded to a considerable extent. (See the map of the Monts Dome, and pp. 71. et seq.) The figure of the Puy du Grand Sarcoui as seen from this point is very remarkable. It is one mass of porous and earthy trachyte, and rises between and in close contact with two regular cones of scoriæ, the Petit Sarcoui and Des Goules. The Puy Chopine is observable in the middle of the sketch,—a strange mass of rock, half granite, half trachyte, resting upon basalt, and rising out of the crater of the Puy de la Goutte.

PLATE VI.

Transversal View of the Southern Chain of Puys, taken from the Summit of the Puy de la Rodde. In the middle appear the broken-down craters of Chaumont, Las Solas, and La Vache; from the bottom of each a lava-current is seen to issue. Those of the two last cones descend together to the east, passing behind the Puy Chaumont, and have formed the lake of Aidat by damming up a river called Le Veyre which flows from the Mont Dor. Below the lake this lava continues to occupy the narrow channel of the river excavated through granite as far as the village of Talande, a distance of fifteen miles. (See the map.)

Beyond the lake are seen the basaltic platform of La Serre, and the Castle of Montredon built upon an insulated peak of basalt, once continuous with the former. To the right are the Puys Combe-grasse, La Taupe, Montgy, Pourcharet, Montjughat, and Monchal. At the foot of the last stands the farm of *M. de Monlosier*, author of "Essai sur les Volcans d'Auvergne," who has lately established himself in the midst of this volcanic desert, and will probably soon succeed in turning its arid plain of scoriæ into productive corn-land; for notwithstanding the great elevation of the spot, it is completely sheltered by the incircling range of volcanic cones, and the fertility of the soil is unquestionable. It is to be hoped, for his sake at least, that the volcanic amphitheatre in which he resides will not soon wake out its of present state of quiescence.

PLATE VII.

Profile of the Montagne de Gergovia from the East. Its two beds of basalt are seen separated by horizontal strata of calcareous peperino. (See page 92.)

PLATE VIII.

Appearance of the Puys Chopine and De la Goutte from the East. The same viewed from the S.W. near Ville-jacques. (See p. 69.) Chopine evidently rises from the crater of La Goutte. The out-cropping of basalt upon which the granite

immediately rests, the alteration of this granite to a certain depth, and the great mass of trachyte which backs the whole hill on the opposite side to the spectator, (and of which only the edges are visible in the sketch,) in immediate contact with, and like the basalt, partly supporting the granite, are points of great interest from their anomaly. It would appear that both trachyte and basalt have here been produced by the same eruption; and it is remarkable that *on that side where the basaltic lava was emitted, there were copious aëriform eructations, (productive of the cone of La Goutte,) and none on the side where the trachyte was protruded*, a circumstance which may be attributed to the tumified but *non-liquid* condition of the latter. (Scrope on Volcanos, p. 122.) Great part of the interest attached to the Puy Chopine derives from its recent production. The perfect shape of the fragmentary cone of La Goutte shows it has wasted very little since its formation.

PLATE IX.

A View of the Valley of Chambon, one of the principal excavations which intersect the Mont Dor. It has its source in the centre of the group, and is directed in a straight line towards the East. The deep gorge called Chaudefour, which forms its upper extremity, is bounded by perpendicular and degraded cliffs of trachyte, offering three or four varieties, superposed to one another in irregular beds with intervening layers of tufa. At no great distance from the central heights, thick beds of basalt overlie first the trachyte, afterwards the fundamental granite, and spreading far and wide into extensive plateaux, descend towards the main valley of the Allier with a gradual slope, which is, however, broken on some points by subsequent excavations, on others, to all appearance, by partial elevations, occasioned perhaps by some of the convulsive throes of the volcano. These sheets of basalt are accompanied throughout their whole extent by irregular deposits of volcanic conglomerate, varying from a coarse basaltic breccia to a fine pumiceous tufa. These conglomerates generally support or alternate with the basalt, particularly towards the lower part of the valley, where the granite is entirely concealed by the accumulated volcanic products. The chief interest of this view lies in the recent volcanic vent of Tartaret, which has exploded in the middle of the valley, and by the quantity of matter it ejected, dammed up the river so as to form the Lake of Chambon, which is easily seen to have extended originally up to the entrance of the Vallée de Chaudefour, but which has been lowered by the wearing away of its canal of discharge. Immediately to the left of the cone of Tartaret may be perceived the commencement of its lava-stream, which continues to occupy the former bed of the river for a distance of 13 miles. Further to the left rises the ruined Château de Murol, once a very strong fortress belonging to the family of D'Estaing.

In this drawing the same colours are applied as in Plate II. except that the trachytic tufas are left uncoloured.

PLATE X.

This general Sketch of the Mont Dor is taken from the Foot of the Puy Gros, whence a bird's-eye view is obtained of the Valley of the Dordogne, in which lies the village of the Baths. At its upper extremity is the deep circus which appears to have been the site of the chief vent of the volcano. The principal peaks which encircle this gorge are named in the references. From those called the Roc de Cuzau on the left, and Le Cliergue on the right, wide platforms of trachyte slope gradually towards the observer. The first form the Plateaux de Durbise and de Langle; they may be seen in the sections afforded by the valley of the Baths to rest upon tufa, this again on a parallel bed of clinkstone, and this on basalt with the interposition of conglomerate. At the Cascade du Mont Dor, immediately above the Baths, this superposition is very evident. (See Plate XI.) The Plateau de Rigolet, on the other side of the valley, is similarly constituted, as may be seen in the valley of La Scie on its opposite side. By this, it is separated from another extensive embranchment consisting of repeated beds of trachyte, and forming the Plateau de Bozat, from beneath which basalt crops out at the Plaine de Chamablanc. The similarity in height, slope, and structure of the Plateaux de Langle and Rigolet lead to the opinion that they were once continuous. Their separation may have been effected by a local earthquake, and enlarged by the erosion of the river. The left of the field of view is occupied by a series of swelling trachytic eminences, of which it is difficult to determine whether they were thrown up in their present irregular and rounded forms, like the trachytic Puys of the Monts Dome, or produced by the unequal weathering of a massive hummock. Basalt appears to crop out also from beneath these trachytes on the N.E. side; but from the quantity of debris of trachyte accumulated along the lines of junction, it is difficult to find any positive fact of superposition. The Puys de Loueire and Trioulerou at the extreme left, are of very slaty trachyte, (clinkstone,) a variety which predominates in that direction.

PLATE XI.

Section of the Beds which compose the Plateau de Langle, disclosed by the ravine of the Cascade du Mont Dor, near the village of the Baths.

PLATE XII.

Panoramic Sketch of the Basin of Le Puy and the Mont Mezen, taken from the Mont d'Ours near that town (Haute Loire).

The view from this point is exceedingly instructive, embracing all the principal features of an interesting and singular country. The Mont d'Ours is a double volca-

nic cone of recent formation, although its craters have disappeared. The eruptions by which it was produced, burst through a vast bed of volcanic breccia and basalt, which is still visible at the village of Ours, and forms a succession of rocky terraces from thence towards Le Puy. It rises near the eastern limit of the freshwater formation, the remains of which are seen on every side, resting against the primitive margin of the cavity in which it was deposited. To the S. E. are seen the highest summits of the Mezen; and from thence to the north the horizon is bounded by a chain of rocky eminences, the ruins of an enormous current of clinkstone, which that volcano has poured forth towards the north. (See p. 129.) The last of these rocks, called *Miaune*, and another not seen in the drawing, near the town of Roche en Regnier, rise from a base of granite on the *further* side of the Loire; the current appearing to have occupied the former bed of that river to some distance, and to have forced it to excavate a fresh one through the whole mass of phonolite. The basaltic currents of the Mezen, which, accompanied by prodigious eluvial accumulations of brecciform conglomerate, overwhelmed the whole surface of the freshwater formation, are observable in all directions; and it is evident from their being found on both sides of the Loire, that this river's actual bed was not yet formed at the æra of their descent. The channel by which the Loire now issues from the basin of Le Puy may be observed to have been pierced entirely through granite, although at the very edge of the calcareous formation;—a remarkable fact, seeming to show that even the softest marls under a protecting cover of basalt resist meteoric erosion far more effectually than granite itself.

It is by the excavation of this narrow, deep and tortuous gorge, that the freshwater lake of the basin of Le Puy was alone discharged. As the channel gradually deepened, the valleys that intersect the freshwater formation were progressively formed. That this process was effected by degrees, and not by any sudden debacle, is proved, 1st, By the undisturbed state of the cones of scoriæ. 2dly, By the great variety of levels at which the basaltic lava-beds occur: they appear in fact, as in the valley of the Limagne, to be the more recent the lower the level they occupy, thus marking the successive steps of the process of excavation. (See p. 158.) It is however possible that some cleft broken through the granitic barrier by subterranean expansion may have occasioned the discharge of the lake in that particular direction.

The prospect to the west is equally interesting. The horizon on that side is limited by the vast chain of volcanic cones, which, commencing at the foot of the primitive heights of La Chaise-Dieu, reaches uninterruptedly to Pradelles. The lava-streams produced by these eruptions have deluged an extensive and nearly level plain, stretching from the foot of the range to Le Puy. This is intersected by the channels of various torrents, and may be seen to consist of repeated currents of basalt, resting on the freshwater limestone. A few insulated cones are scattered over the plain, and some occur at a considerable distance from the line upon which the greater number of eruptions have broke forth. That near the

village of Chaspinhac, on the slope of a massive granitic embranchment rising from the river Sumène, is remarkable for its elevated position. It has apparently furnished the lava-current of the Plateau de Fay, which, however, is now separated from it by the deep gorge by which the Sumène joins the Loire. The large cone of Bar, near Alègre, which still presents a very perfect crater, and those of St. Geneys and Couran, are conspicuous in the distance; as well as those in the opposite direction which rise from the Forest of Brègise, near Prèzailles, on the western slope of the Mezen.

The valley of the river Borne, from which rises the town of Le Puy, the capital of the department of the Haute Loire, is not the least interesting part of the view. Its numerous feeders, which unite near the remarkable insulated and regularly columnar rock called "The Organ of Expailly," have each their channel cut through a system of basaltic beds, generally columniform, often double, with a thick bed of conglomerate interposed, and resting on the freshwater limestone strata. The great mass of volcanic breccia called the Rocher Corneille, is seen rising above Le Puy, as well as the spiry pinnacle of St. Michel, formed of the same substance, and standing up in the middle of the town. A similar mass rises from the town of Polignac, as seen above, at a distance of about four miles. These rocks were favourable sites, of course, for chateaux-forts in the *good old* times of rapine and butchery; and most of the towns of the central provinces of France were built under the protection of some such fortress.

There are perhaps few spots on the globe which offer a more extraordinary prospect than this. To the eye of a geologist it is superlatively interesting, exhibiting in one view a vast theatre of volcanic formation, containing igneous products of various nature, belonging to different epochs, and exhibited under a great diversity of aspect.

When the panoramas of Paris and Petersburg, Spitzbergen and Naples, have ceased to amuse, and novelty is required, Mr. H. A. Barker cannot do better than turn his steps to Le Puy, and wield his magic pencil on the summit of the Mont d'Ours.

PLATE XIII.

View of the Extremities of the South-western lateral Embranchments from the Basaltic Platform of the Coiron, as seen from the neighbourhood of St. Jean le Noir, on the road from Villeneuve de Berg to Viviers (Ardêche). (See p. 133, and the general map of the district.)

PLATE XIV.

Volcanic Cone and Current of Jaujac (Ardêche). The cone rises from the middle of a trough-shaped valley, occupied by a coal-formation, and bounded on either side by ranges of granite and gneiss. A lava-current may be seen to proceed from

a breach in the circuit of the crater, and descend into the valley of the Alignon, which it once filled to a considerable depth and width. The excavation since effected by the river has exposed a mural range of columnar basalt about 200 feet high, and extending uninterruptedly into the further valley of the Ardêche, and even some distance down the course of the latter river. On the edge of this cliff-range stands the village of Jaujac. In the distance to the left are seen the primitive heights of the Haut Vivarais; and through the opening afforded by the valley of Prades, a part of the sloping basaltic platform of the Coiron. The group of hills that rise in the centre of the view are of granite. The summit of another neighbouring volcanic cone, called La Gravenne de Soulliols, is just visible on the left.

PLATE XV.

The Valley of Montpezat. This view is taken near the confluence of the torrents Fontaulier and Pourseille, whose channels are eaten out of a massive bed of basalt produced by the volcanic cone which rises to the extreme left. The platform dividing them terminates in an exceedingly acute angle, composed of very beautiful and regular columns resting on granite. A ruined castle stands on the point of this angle, and adds its picturesque effect to the natural beauties of this very lovely scene,—to which my awkward pencil is wholly unable to do justice. The valley is encased by the primitive buttresses of the platform of the Haut Vivarais. Their skirts are clothed with rich forests of Spanish chesnut. In the distance rises a volcanic cone of inferior size to that of Montpezat, and which has not produced any lava-stream.

It may be remarked that the vast amount of excavation which has taken place in this valley, since the epoch at which it was filled up to the level of the Castle of Pourchirol with liquid basalt, and this not only through the basalt but to a depth of more than 100 feet through the underlying granite, (which is of a very hard compact nature,) *can* only have been effected by the erosive force of *the torrents that flow there at present;* since any more general and violent rush of waters, of the nature of a deluge or debacle, would not have left undisturbed the two cones of loose scoriæ, of which parts are seen in our sketch, and of which the materials are so incoherent that the foot sinks ankle-deep into them.

PLATE XVI.

La Coupe d'Ayzac, a volcanic cone with a very perfect crater, near Antraigues (Ardêche). The crater being on the opposite side of the hill is not seen in the drawing.

A lava-current descending from it has been cut through by the river Volant. Its section forms a vertical rock, exhibiting three apparently distinct ranges of co-

lumns. Those of the lower story are very regular. The basalt rests on either side against the granitic cheeks of the valley whose bottom it occupied. This drawing was taken from the outskirts of the village of Antraigues, and from the foot of a remarkably isolated rock of columnar basalt, lying precisely at the same level with those seen on the opposite side of the river, with which it was certainly once continuously united. Similar but larger patches of the same current of basalt are visible on many points down the valley of the Volant for a distance of four or five miles, particularly in its concave angles. The excavation to which their insulated position is owing, suggests the same reflection as that seen in the preceding engraving of the valley of Montpezat. (See p. 162.) By comparing this drawing with that given by Faujas of the same cone, it will be seen that in his directions to his draughtsman he must have trusted to memory, and that a very bad one. Besides the complete dissimilarity of form, it is absolutely impossible to see the crater of La Coupe and the basaltic range of columns above the river, together, from any one spot.

PLATE XVII.

Sections of the Primitive Platform of Central France from N. to S. and from E. to W.

PLATE XVIII.

Fig. 1. Ideal Profile of the principal Hills in the immediate neighbourhood of Clermont, showing the various heights at which beds of basalt are now found in the Basin of the Limagne, and tending to prove the gradual excavation of that valley. (See p. 161.)

Fig. 2. Section of the Mont Mezen and Part of the Freshwater Formation of Le Puy (Haute Loire). This section is taken from M. Bertrand Roux's work on the Environs of Le Puy.

N.B. The two panoramic views, Plates II. and XII. may be mounted on canvass, and, by a few loops through which a thin hoop of whalebone is passed, suspended so as to admit the head within the circle, and thus present completely the effect of a panorama in miniature.—The publisher has directions to keep some impressions prepared in this manner in case they should be required.

THE END.

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